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Potential Growth of the Southern Pine Plywood Industry

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T. C. Nelson, Director

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POTENTIAL GROWTH OF THE SOUTHERN PINE PLYWOOD INDUSTRY

Timber supplies and costs of logging, manufacturing, and transportation were evaluated for the South, west coast, and Rocky Mountains by linear programming. The results indicate that by 1975 the South will be supplying 30 percent of the Nation's softwood plywood, while maintaining its current proportion of lumber output.

Until 1963, softwood plywood was manufactured largely within the Douglas-fir region on the west coast. Commercial production of southern pine plywood began that year. By the end of 1967, 34 plants costing more than $100 million and capable of supplying 21 percent of the industry's production had been installed in the southern pinery (table 1).

Table 1.—*Distribution of softwood plywood plants, 1959-1967* [1]

State	1959	1960	1961	1962	1963	1964	1965	1966	1967
California	27	28	29	25	22	22	19	18	17
Oregon	78	85	88	88	89	93	89	91	89
Washington	36	36	35	36	37	37	37	31	32
Colorado	..	..	..	..	..	..	1	1	1
Idaho	1	2	2	2	2	3	4	4	4
Montana	1	3	3	4	5	5	6	6	6
New Mexico	..	..	..	..	..	..	..	..	1
Alabama	..	..	..	..	..	..	1	1	3
Arkansas	..	..	..	..	1	1	3	3	4
Florida	..	..	..	..	..	..	..	..	1
Georgia	..	..	..	..	..	..	..	1	4
Louisiana	..	..	..	..	..	..	3	7	9
Maryland	..	..	..	..	..	..	..	1	1
Mississippi	..	..	..	..	..	..	1	3	4
North Carolina	..	..	..	..	..	..	2	3	4
Texas	..	..	..	..	..	2	3	3	3
Virginia	..	..	..	..	..	..	1	1	1
Total	143	154	157	155	156	163	170	174	184

[1] Source: Sherman *(13)*.

A number of factors have contributed to the shift in the plywood industry's location. Timber availability is a major consideration. For two decades, timber inventories have been building up in the South *(17)*. But in Oregon and Washington, log supplies have been falling short of installed lumber and plywood processing capacity since the 1950's *(2)*. The chronic shortage of logs in the West has been aggravated by exports to Japan, which increased from a trivial volume in 1960 to over 1.5 billion board feet in 1967 *(20)*.

Other circumstances have also enhanced the South's position. The advent of high-speed lathes and lathe chargers made it feasible to peel small pine logs. In recent years, sheathing grades of plywood have risen to a predominant position in the market, and the southern pines are highly suitable for sheathing. The South is also favored by its proximity to a majority of the Nation's plywood markets and its low labor costs and year-round forest operations in gentle terrain.

Even with the growth already achieved, the South lacks enough plywood capacity to supply local and nearby eastern markets; shipments from the West fill out demands. The price for western plywood consumed in the East must cover the cost of stumpage, logging, manufacture, and transcontinental shipment. In effect, a price umbrella is established for southern manufacturers who can apparently supply plywood to eastern markets at a lower price than that determined by shipments from the West. This reasoning implies that the plywood industry will continue to expand in the South. The objective of the economic analysis described in this paper is to explore the limits to which the South's plywood industry could grow by 1975.

Problem

Although the main purpose was to study the southern pine plywood industry, other products and timber areas had to be considered. Competition with plywood manufacturers in the West had to be accounted for, and competition between plywood and lumber mills for sawtimber supplies could not be ignored.

In the long run, the allocation of any region's timber between plywood and lumber depends upon the relative ability of each industry to compete for the region's available stumpage. The industry which has the greater margin between average market prices and average costs has the greatest competitive strength. Since it can pay more for stumpage if necessary, it can be expected to grow at the expense of the other industry if timber shortages develop.

The key question, therefore, is: What is the potential for the major timber areas of the country to compete in plywood and lumber markets? The answer indicates future trends in the location of both industries.

Other industries, especially the pulp and paper industry, are expected to claim a total of almost 20 percent of the Nation's sawtimber cut in 1975. The claims of these industries on sawtimber were accounted for by deducting them from the total timber supply.

Analytic Model

The concepts of traditional location theory were employed to determine the ability of plywood and lumber manufacturers to compete both within a timber region and between regions *(5)*. The interdependent equilibrium location of both industries was found by using linear programming to jointly minimize total production and transportation costs *(7)*. At equilibrium, no manufacturer in any region finds it profitable to change his product, plant location, or markets. At the same time, timber owners cannot be paid more than they are for stumpage, and consumers cannot save by changing their sources of supply. The year 1975 was chosen for estimating the equilibrium location for the plywood and lumber industries. Presumably, that year is far enough in the future for processing plants to be depreciated in one location and built in another.

The model for simultaneously deriving the long-run equilibrium location of plywood and lumber production was minimize:

$$\text{Total costs} = \sum_{i=1}^{22} \sum_{j=1}^{43} (L_i + C_i^p + T_{ij}^p) X_{ij}^p + \sum_{i=1}^{24} \sum_{j=1}^{43} (L_i + C_i^u + T_{ij}^u) X_{ij}^u \qquad (1)$$

Subject to:

$$\sum_{i=1}^{22} X_{ij}^p = D_j^p \qquad [j = 1\text{-}43] \qquad (2)$$

$$\sum_{i=1}^{24} X_{ij}^u = D_j^u \qquad [j = 1\text{-}43] \qquad (3)$$

$$\sum_{i=11}^{13} X_{ij}^p \geq 0.20\, D_j^p \qquad [j = 1\text{-}43] \qquad (4)$$

$$\sum_{i=11}^{24} X_{ij}^u \geq 0.30\, D_j^u \qquad [j = 1\text{-}43] \qquad (5)$$

$$\sum_{j=1}^{43} X_{ij}^p \leq S_i^v \qquad [i = 1\text{-}22] \qquad (6)$$

$$\sum_{j=1}^{43} (X_{ij}^p + X_{ij}^u) = S_i^t \qquad [i = 1\text{-}24] \qquad (7)$$

$$X_{ij} \geq 0 \qquad [i = 1\text{-}24;\ j = 1\text{-}43] \qquad (8)$$

where:

p = plywood

u = lumber

v = timber suitable for plywood or lumber

t = total available timber resource, all of which can be sawn into lumber but only part of which is suitable for plywood

i = 24 timber supply regions

j = 43 timber product consumption regions

L_i = the cost of logging 1 M board feet of timber in supply region i

C_i = the cost of processing 1 M board feet of timber in supply region i

T_{ij} = the cost of transporting 1 M board feet, log equivalent, of timber from supply region i to consumption region j

D_j = consumption requirement at j in M board feet, log equivalent

S_i = timber supplies at i, in M board feet log scale, and

X_{ij} = the unknown variables of the problem, which are the M-board-foot equivalents of a product processed in i and shipped to j.

Equation 1 states that the total cost of logging, processing, and transporting plywood and lumber is to be minimized. Restrictions are given in equations 2 through 8. Equation 2 requires the sum of all plywood shipments received at each market region to equal the region's plywood consumption. Equation 3 states the same for lumber. Equation 4 requires at least 20 percent of the plywood consumed in all regions to come from the three westernmost timber regions. It was assumed that only these regions can make A-face plywood, which is expected to account for 20 percent of production in 1975. Equation 5 forces at least 30 percent of the lumber consumed in all markets to be of western species. That proportion of the lumber consumed in the South is western, even though southern pine can be purchased at a lower price. It was assumed, therefore, that 30 percent of consumption is based on special characteristics of western species rather than on price. Equation 6 states that shipments of plywood from each supply region cannot exceed the availability of timber suitable for its production. Equation 7 requires each region's entire timber availability to be manufactured and shipped out in the form of plywood or lumber. Equation 8 is a standard linear programming requirement which prohibits negative shipments.

Four simplifying assumptions are implicit in the model: 1. Stumpage and product markets are perfectly competitive. 2. The mix of plywood and lumber consumed in all demand regions is the same as the national aggregate, and the timber of all supply regions is capable of yielding the mix, except as noted in equations 4 and 5, 3. Unit costs of logging, manufacturing, and transporting do not vary with the level of activity. 4. Product demand and timber supply are perfectly price inelastic.

INPUT DATA

This section deals with the data required by the model and their sources and methods of compilation. The reader mainly interested in results of the analysis can turn to page 16.

Timber Supply Regions

The concern is not with specific plant locations but with the future location of plywood and lumber production within broad geographic areas. The Nation's three major softwood timber areas are the west coast, the Rockies, and the South. These areas were subdivided into a total of 22 domestic timber supply regions (fig. 1). State lines formed the boundaries except in Washington, Oregon, and California. Those States were divided into east and west sides to reflect significant differences in timber type and supply. A point centrally located with respect to each region's timber inventory was chosen for computation of product transportation costs from the region.

British Columbia was divided to form two lumber supply regions. The United States currently imports 15 percent of its softwood lumber consumption, and British Columbia is the principal supplier. A 20-percent tariff on imported softwood plywood virtually eliminates foreign trade in it.

The Lake States and the Northeast supply very little of the Nation's softwood lumber. Furthermore, the softwoods native to these areas have not yet been shown to be suitable for plywood manufacture. Hence, the Lake States and the Northeast were not considered to be supply regions. Lumber made there was deducted from local requirements.

Consumption Regions

Demand for plywood and lumber was partitioned among 43 consumption regions (fig. 2). The boundaries are those of the 50 Major Trade Regions in the Rand McNally *Commercial Atlas and Marketing Guide (11)*, except that seven regions were consolidated with adjacent

ones to reduce the cost of computations. The major city in each region was selected to represent the point of consumption for determining transportation costs.

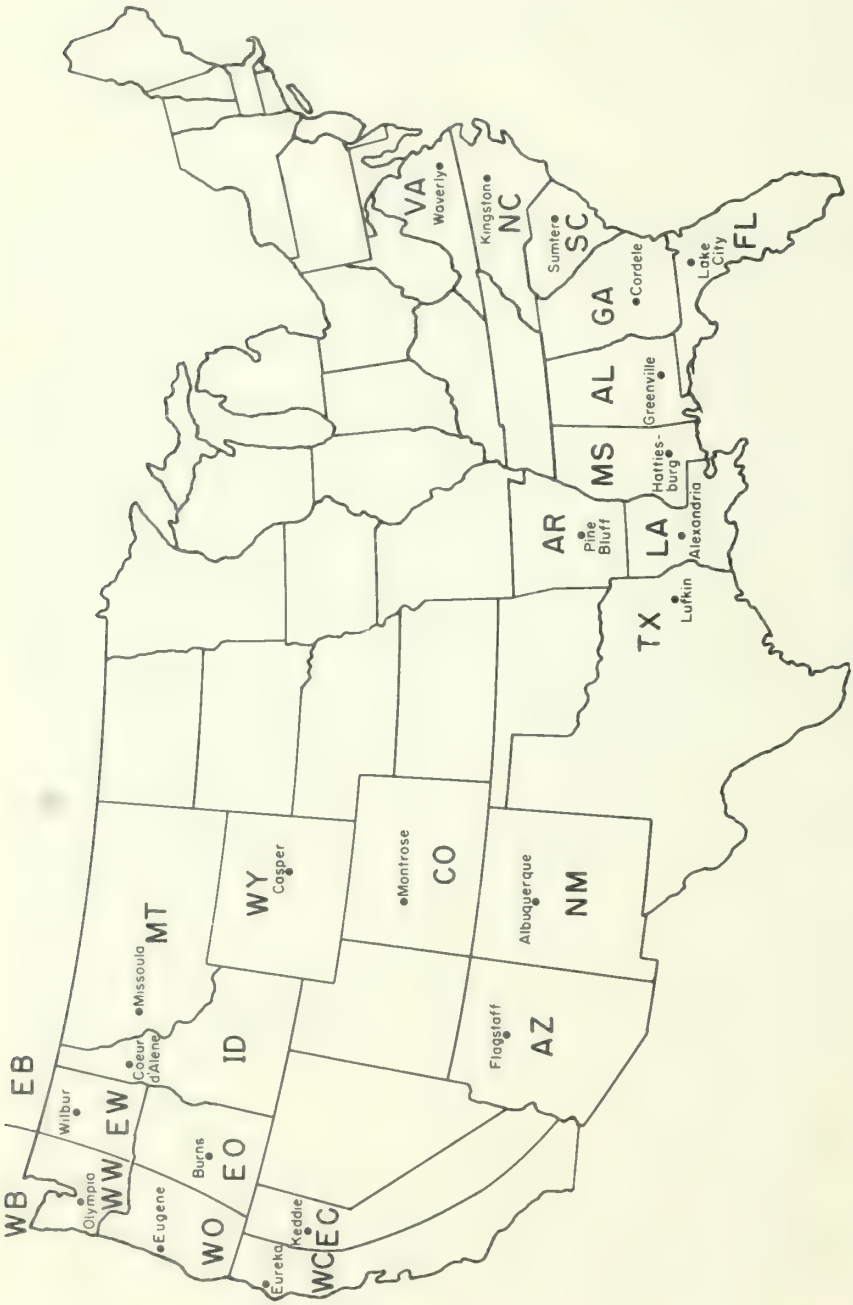

Figure 1.—*Timber supply regions.*

Figure 2.—*Lumber and plywood consuming regions.*

Logging Costs

Differences in average logging costs are important determinants of the competitive relationships among regions. The estimates of average regional logging costs came from USDA Forest Service timber appraisal documents for 1966. To assure the public a fair price for its timber, a minimum price is set on national forest timber advertised for sale. This price is set by deducting manufacturing and logging costs from f.o.b. product prices at mills adjacent to the sale. The costs are summarized by national forest administrative regions in terms of local log rules. These, and all other input data, were converted to the International ¼-inch log rule. The costs for the southern Rockies were adjusted upward because increasingly difficult logging chances will probably be encountered there. The resulting average costs are given in table 2.

Table 2.—*Logging and manufacturing costs per M board feet of logs (International ¼-inch rule) for plywood and lumber, by region, 1975*

Region	Logging	Plywood labor and glue	Lumber manufacturing
		Dollars	
Southern pine regions	24.02	31.69	33.21
Washington			
Western	30.14	45.92	32.99
Eastern	26.44	49.17	33.51
Oregon			
Western	30.14	45.92	32.99
Eastern	26.44	49.17	33.51
California			
Western	28.35	45.92	32.11
Eastern	28.35	49.17	32.11
Idaho	34.22	49.17	33.94
Montana	34.22	49.17	33.94
Wyoming	33.24	49.17	35.97
Colorado	33.24	49.17	35.97
New Mexico	31.43	49.17	32.20
Arizona	31.43	49.17	32.20
British Columbia			
Western [1]	30.14	.	32.99
Eastern [1]	34.22	...	33.94

[1] Western and eastern British Columbia were assigned the same logging and lumber manufacturing costs as western Washington and Idaho, respectively.

Manufacturing Costs

Average regional lumber manufacturing costs were also estimated from 1966 Forest Service timber appraisal data. It was assumed that regional cost differences would remain constant through 1975.

Because plywood plants are new to the South, manufacturing costs are not available. Regional differences in cost are all that the model requires, however, and they were approximated by comparing labor and gluing costs in each region. Labor makes up 58 and glue 8 percent of total plywood manufacturing costs, excluding wood *(20)*. Since the equipment for manufacturing a given plywood mix is about the same everywhere, other variable and fixed costs were assumed to be equal in all regions.

From data collected in Washington and Oregon, Smith and Gedney *(14)* estimated the plywood output per man-hour as 151 square feet (3/8-inch basis) in integrated plants. At a conversion ratio of 1.9 square feet of plywood per board foot, 12.58 man-hours are required to process a thousand board feet of logs. This labor requirement was applied in all regions. Therefore, the differences in computed labor costs between regions arise from differences in wage rates.

For many years workers in forest industries have earned approximately twice as much per hour in the West as in the South (fig. 3). The hourly wage in 1966 averaged $1.58 in the Southern States and $2.94 in the West *(15)*. To these hourly rates were added 11.15 percent for fringe benefits *(12)*, which increased the differential slightly.

Gluing costs are considerably higher in the southern regions than elsewhere for two reasons. First, the plants there are using expensive phenolic-resin adhesives. Second, glue spreads in the South must be heavier to prevent poor glue lines caused by high ambient temperatures, high absorptiveness of springwood, and roughness of southern pine veneer *(4)*.

A major supplier of adhesives to the plywood industry provided average prices for each major timber area. The costs per M square feet of plywood were estimated to be $5.05 in the South, $2.53 on the west coast, and $4.24 in the inland regions of the West. Regional differences in manufacturing costs are presented in table 2.

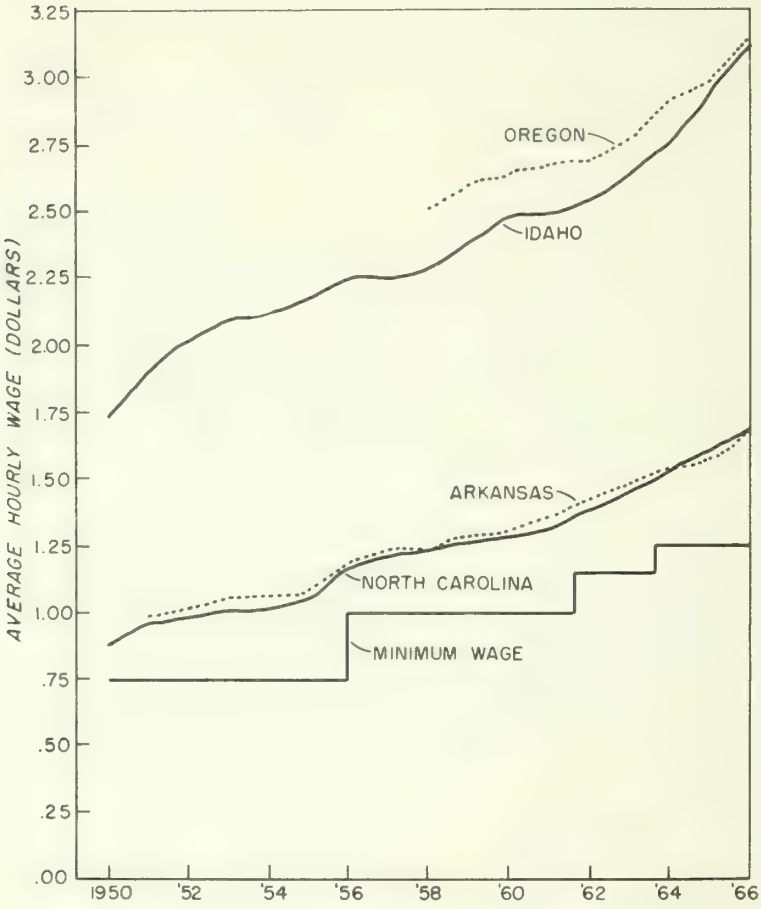

Figure 3.—*Average hourly wages of workers in forest-products industries in four States, 1950 to 1966.*

Transportation Costs

With 22 timber regions, 43 market regions, and two products, a complete listing of transportation rates would require 1,892 entries. The matrix doubles if both rail and truck hauls are considered, and the possible water routes add even more. Since railroads are competitive with these other modes of transportation, rail rates were used in the analysis. To further simplify, equations were developed to relate cost to hauling distance. The equations were based on 100 routes systematically selected to represent all situations. Rates for the sample routes were obtained from railroad companies for shipments of 40 tons, the average weight of a carload of plywood or lumber *(6)*.

Rail rates per mile depend upon the region of origin as well as the destination. Also, plywood and lumber do not always have the same rate. These complications made necessary three equations for southern shipments:

$$C_1 = 17.15 + 0.0545D \qquad R^2 = 0.999$$

$$C_2 = 16.97 + 0.0486D \qquad R^2 = 0.988$$

$$C_3 = 8.71 + 0.0530D \qquad R^2 = 0.973$$

where:

C_1 = cost per cwt. for plywood shipped from any southern pine region into Official Territory (Northeastern United States)

C_2 = cost per cwt. for lumber shipped from any southern pine region into Official Territory

C_3 = cost per cwt. for plywood or lumber shipped from any southern pine region to cities not in Official Territory

D = distance in miles, short-line haul.

A blanket rate of $1.41 per cwt. applies to lumber shipments from Washington, Oregon, California, Idaho, and Montana into Official Territory. For all other shipments of both lumber and plywood from the West, a single equation was appropriate:

$$C = 11.11 + 0.1823D - 0.0000118D^2 \qquad R^2 = 0.967$$

Short-line haul distances between all combinations of supply and demand regions were computed from a Rand McNally table and map *(10)*.

Table 3 shows the weights assigned to each product, by area of origin. These weights were calculated for lumber at 15-percent moisture content, plywood at 8-percent moisture content, and specific gravities taken from the *Wood Handbook (16)*.

Table 3.—*Product weights, by major softwood region*

Region	Plywood, per M sq. ft., 3/8-inch basis	Lumber per M bd. ft.
	Pounds	
South	1,190	2,210
Pacific coast	1,125	2,090
Inland West	1,005	1,800

Consumption

The American Plywood Association (APA) recently predicted that 20.4 billion square feet (3/8-inch basis) of plywood will be consumed in the Nation in 1975 *(8)*. This estimate was accepted and divided among consuming regions (table 4) in the proportions reported by the APA for 1966 shipments *(1)*.

Table 4.—*Requirements for plywood, 3/8-inch basis, by consuming region, 1975*

Region	Requirements	Region	Requirements
	Million sq. ft.		*Million sq. ft.*
Atlanta	592	Memphis	306
Birmingham	265	Miami	224
Boston	755	Milwaukee	408
Buffalo	245	New Orleans	347
Charlotte	775	New York	1,897
Chicago	1,346	Norfolk	306
Cincinnati	286	Oklahoma City	265
Cleveland	347	Omaha	204
Columbus	143	Philadelphia	755
Dallas	490	Phoenix	143
Denver	327	Pittsburgh	265
Des Moines	306	Portland	1,081
Detroit	816	St. Louis	367
Houston	265	St. Paul	571
Huntington	61	Salt Lake City	265
Indianapolis	245	San Antonio	143
Jacksonville	224	San Francisco	1,346
Kansas City	408	Seattle	898
Knoxville	224	Spokane	265
Little Rock	123	Tampa	143
Los Angeles	1,265	Washington	469
Louisville	224	Total	20,400

The USDA Forest Service estimated that the Nation will require 33.7 billion board feet of softwood lumber in 1975 *(17)*. This volume was distributed among the consumption regions in proportion to their 1967 populations *(11)*. Slight adjustments were made to allow for regional differences in residential construction practices *(9)*.

Approximately 1.42 billion board feet of lumber will be produced in the Northeast and the Lake States in 1975 if these areas' proportions of softwood lumber production do not change *(18)*. This volume was deducted from the consumption requirements in the

calities where it was produced. As a result, net consumption in e demand regions in 1975 is 32.28 billion board feet. It is distribud as shown in table 5.

ble 5.—*Net requirements for lumber, by consuming region, 1975*

Region	Requirements	Region	Requirements
	Million bd. ft.		*Million bd. ft.*
lanta	872	Memphis	549
rmingham	613	Miami	323
ston	968	Milwaukee	581
ffalo	452	New Orleans	613
arlotte	1,323	New York	4,325
icago	2,130	Norfolk	613
ncinnati	517	Oklahoma City	452
eveland	775	Omaha	290
lumbus	291	Philadelphia	1,614
llas	968	Phoenix	290
nver	646	Pittsburgh	807
s Moines	452	Portland	355
troit	1,453	St. Louis	710
uston	549	St. Paul	710
ntington	258	Salt Lake City	226
dianapolis	387	San Antonio	323
cksonville	323	San Francisco	1,227
nsas City	484	Seattle	452
oxville	420	Spokane	323
tle Rock	258	Tampa	194
s Angeles	1,840	Washington	904
uisville	420	Total	32,280

mber Availability

The projections of sawtimber growth and cut found in *Timber ends in the United States (17)* were the source of the timber availility estimates for 1975. In the South, it was assumed that net nual sawtimber growth in 1975 would be available for cutting. n the national forests in the West, the planned allowable cut was nsidered available. On other lands in the West, the projection of t was accepted. Since these projections of cut and growth are for eas much larger than the timber regions of the model, volumes had be assigned to the regions in proportion to their current timber ventory. The results are given in the first column of table 6. This lumn also includes the 6.5 billion board feet of lumber imports proted to come from British Columbia in 1975. Lumber imports, in fect, add to the domestic timber supply.

Table 6.—*Timber availability, by region, 1975*

Timber region	Timber available	Deduction for pulpwood	Other Deductions [1]	Available for lumber and plywood	Net volume suitable for plywood
	– – – Billion bd. ft., Int. ¼-inch log rule – – –				
Virginia	1.14	0.34	0.04	0.76	0.46
North Carolina	2.48	.45	.02	2.01	1.16
South Carolina	1.24	.47	.10	.67	.40
Georgia	2.72	1.26	.06	1.40	.68
Florida	1.05	.63	.09	.33	.14
Alabama	2.77	.85	.09	1.83	1.21
Mississippi	1.64	.41	.07	1.16	.73
Louisiana	2.17	.43	.07	1.67	1.16
Arkansas	2.53	.26	.07	2.20	1.46
Texas	2.12	.25	.08	1.79	1.19
Washington					
Western	4.98	.76	1.32	2.90	2.90
Eastern	1.46	.30	.05	1.11	1.11
Oregon					
Western	7.03	.23	.61	6.19	5.70
Eastern	2.24	.09	.07	2.08	1.93
California					
Western	2.46	.00	.10	2.38	2.14
Eastern	2.98	.00	.09	2.89	2.62
Idaho	1.73	.02	.01	1.70	1.29
Montana	1.53	.02	.01	1.50	1.14
Wyoming	.38	.00	.00	.38	.29
Colorado	.83	.00	.00	.83	.83
New Mexico	.41	.00	.00	.41	.31
Arizona	.39	.04	.00	.35	.29
British Columbia					
Western	3.25	.	.	3.25	.
Eastern	3.25	.	.	3.25	.
Total	52.78	6.81	2.95	43.02	28.94

[1]Includes poles, piling, log exports, and the log equivalents of lumber exports.

While the lumber industry can process all trees classed as sawtimber, utilization standards are somewhat higher in the plywood industry. In the South, plywood plants aim for an average bolt of 12 to 14 inches d.i.b. with a minimum size of 10 inches. Veneer yield is very sensitive to bolt characteristics including crook and the number and size of knots. In the South, it was assumed that all of the sawtimber volume in trees 13 inches d.b.h. and larger could be processed into veneer. Although many of the butt cuts in smaller trees would be acceptable for plywood, that volume is compensated

or by the unusable volume in the upper bole of trees 13 inches d.b.h. nd larger. To reflect slightly different utilization standards, 15 nches d.b.h. was assumed to be the minimum tree size for plywood n the West.

Timber Trends in the United States (17) contains a projection f the distribution of harvest, by d.b.h. class, in the year 2000 for he major timber-growing areas. The diameter distribution of cut n 1975 was projected by interpolating between 1962 and 2000.

The amount of timber available was reduced to account for roducts other than plywood and lumber made from sawtimber-ized trees. The pulp and paper industry is the most important ompetitor for sawtimber. Traditionally, the bulk of the roundwood sed by this industry has come from trees below sawtimber size, ut the situation is changing. For example, a survey by Christopher [1] ndicated that 66 percent of the pulpwood harvested in the Deep outh comes from sawtimber-sized trees—45 percent from trees 9 o 13 inches d.b.h. and 21 percent from trees larger than 13 inches.

Approximately 33.75 million cords of round softwood may be equired by the pulp and paper industry in 1975 *(17)*. It was assumed hat the pulp and paper industry has superior bargaining power in tumpage markets because of the tremendous capital investment it nust protect. Hence its requirements were deducted from gross imber availability in proportion to recent estimates of pulpwood roduction by State *(21)*. A cord was assumed to equal 80 cubic eet of solid wood, and factors to convert from cubic feet of round-vood to board feet (International ¼-inch log rule) were derived from *Timber Trends in the United States (17)*, where sawtimber inventory n each State is given in both cubic feet and board feet. A total of .826 billion board feet was deducted from gross timber availability or the pulp and paper industry (table 6). Christopher's results [1] vere used to divide this deduction between the two size classes of imber.

Other deductions from timber availability shown in table 6 vere for poles and piling, lumber exports, and log exports. Poles nd piling are expected to drain about 630 million board feet of awtimber-sized material in 1975. The projected lumber export in 975 will reduce the supply of available timber by 780 million board eet. Log exports from the Pacific coast to Japan have become a ignificant drain on the forests of that area, but legislation limiting xports from Federal lands should allay the recent trend. Hence, nly 1,525 million board feet of log exports were deducted in western Vashington and Oregon.

[1] Christopher, J. F. Unpublished data collected at the Southern Forest Exp. Sta., USDA Forest Serv., New Orleans, La. 1964.

RESULTS AND CONCLUSIONS

In applications of linear programming, it is helpful to interpret the results literally at the outset. Deficiencies in the model can be considered before drawing conclusions. A number of estimates of the South's plywood production potential were made, but only two are reported here. The first is based on the most favorable cost assumptions with respect to southern plywood manufacture, and the second on the most unfavorable.

The first solution assumes a continuation of historically low southern wage rates. In it, southern costs are $14.23 less than those of the Pacific coast regions for processing a thousand board feet of logs into plywood (table 2). In the second solution, plywood manufacturing costs are assumed to be equal in all regions.

The first solution indicates that in the long run the South could support 59 percent of the Nation's plywood production (table 7). That is, the location of the plywood and lumber industries would be stable if 59 percent of the Nation's plywood were eventually produced in the South. The solution indicates that while the South's share of plywood production will greatly increase, its share of lumber production will remain relatively stable at 22 percent of national production.

In the second solution, the South's proportion of the plywood industry is reduced to 36 percent (table 8).

Table 7.—*Location of plywood and lumber production in the first solution*

Timber region	Plywood	Lumber
	– *Percent* –	
Virginia	4.3	0.9
North Carolina	10.8	2.5
South Carolina	3.1	1.0
Georgia	3.4	3.0
Florida	1.3	.6
Alabama	8.5	2.7
Mississippi	3.7	2.3
Louisiana	5.9	3.1
Arkansas	13.6	2.2
Texas	4.8	3.8
South	59.4	22.1
Washington		
Western	16.5	3.3
Eastern	.0	3.3
Oregon		
Western	10.7	14.9
Eastern	.0	6.2
California		
Western	12.8	3.0
Eastern	.0	8.6
Pacific area	40.0	39.3
Idaho	.0	5.0
Montana	.0	4.4
Wyoming	.0	1.1
Colorado	.0	2.5
New Mexico	.0	1.2
Arizona	.6	.9
Rocky Mountain area	.6	15.1
British Columbia	.	19.3
Other domestic timber areas	.	4.2
Total	100.0	100.0

Table 8.—*Location of plywood and lumber production in the second solution*

Timber region	Plywood	Lumber
	– Percent –	
Virginia	1.2	1.9
North Carolina	9.6	2.9
South Carolina	3.1	1.0
Georgia	3.4	3.0
Florida	1.3	.6
Alabama	3.8	4.2
Mississippi	1.3	3.0
Louisiana	.0	4.9
Arkansas	8.1	4.0
Texas	4.6	3.9
South	36.4	29.4
Washington		
Western	16.2	3.4
Eastern	.0	3.3
Oregon		
Western	9.4	15.4
Eastern	2.6	5.3
California		
Western	10.6	3.6
Eastern	2.2	7.9
Pacific area	41.0	38.9
Idaho	9.8	1.9
Montana	7.8	2.0
Wyoming	2.7	.3
Colorado	1.7	1.9
New Mexico	.0	1.2
Arizona	.6	.9
Rocky Mountain area	22.6	8.2
British Columbia	.	19.3
Other domestic timber areas	..	4.2
Total	100.0	100.0

A comparison of the two solutions indicates that a large part of the South's potential is based on maintaining favorable manufacturing costs. Even if the favorable cost differential were completely eroded, the South would have an advantage in producing slightly over a third of the Nation's plywood. The sources of that advantage are low logging costs and low transportation costs to markets in the populous Eastern United States. These two factors also favor the southern lumber industry, which responds to a lower level of plywood production in the second solution by increasing its output to 29 percent of national requirements.

In terms of product volumes, the South's plywood production potential lies between 7 and 12 billion square feet in 1975 (table 9). The projected level of timber availability in the South enables the area to increase its combined plywood and lumber production appreciably. In the Pacific States, output of both products declines because of the projected reduction in timber availability.

As the southern plywood industry approaches its growth potential, competition for timber will raise stumpage prices, and competition in the market will lower f.o.b. plywood prices. Thus, southern manufacturers will slowly lose their advantage.

These forces of competition have not yet worked themselves out. In 1966, the average selling price per M board feet (Scribner)

Table 9.—*Current and projected production of lumber and plywood, by area*

Product and area	Current [1]	Projected	
		First solution	Second solution
	– – – – *Billion square feet* – – – –		
Plywood			
South	1.72	12.12	7.43
Pacific	10.28	8.16	8.36
Rockies	1.00	.12	4.61
Total	13.00	20.40	20.40
	– – – – *Billion board feet* – – – –		
Lumber			
South	6.61	7.45	9.91
Pacific	17.40	13.20	13.11
Rockies	4.18	5.09	2.76
Total	28.19	25.78	25.78

[1] Current plywood figures are for 1967 *(8, 13)*. Lumber figures are for 1966 *(19)*.

of west-side Douglas-fir stumpage from national forest lands was $43.32, while national forest stumpage prices throughout the South averaged $38.12 *(3)*. As programmed for the second solution, firms had to pay $6.12 more per M board feet for logging in western Oregon than in Louisiana and $11.26 more to ship their plywood to New York City. Applying the proper conversion factors, plywood could be delivered from Louisiana to New York City for $11.15 per M square feet less than from western Oregon. Labor cost differentials would make the margin for Louisiana mills even larger. Yet since most plywood consumed in New York City still comes from the West, the price in that market is set by transactions with western mills. If southern manufacturers get the same delivered price for their product, they acquire the $11.15 as an extraordinary gain.

The linear programming model gives the stumpage prices that would result if the plywood industry were to attain its full potential in the South. Values were lowest in western Washington and Oregon. In table 10, stumpage values on the west coast were set at zero, and all other values were expressed relative to them. Stumpage in every southern region must rise to more than $20 above the price of comparable stumpage on the Pacific coast before the incentive for locational change is eliminated.

Although these prices are theoretical, they demonstrate the inherent value of southern pine as compared to timber in other major forest areas. This value will be made explicit as the South experiences growth in its plywood industry, its burgeoning pulp and paper

Table 10.—*Relative values of stumpage among regions in the second solution*

Region	Stumpage differential
	Dollars per M bd. ft.
Virginia	28.32
North Carolina	27.19
South Carolina	25.64
Georgia	23.21
Florida	24.98
Alabama	22.55
Mississippi	21.45
Louisiana	20.56
Arkansas	22.77
Texas	21.66
Washington	
Western	.00
Eastern	8.16
Oregon	
Western	.00
Eastern	7.44
California	
Western	4.97
Eastern	7.65
Idaho	.67
Montana	1.93
Wyoming	11.51
Colorado	7.13
New Mexico	13.84
Arizona	9.70

industry, and its revitalized pine lumber industry. Hence, the prospects for profitable forest management look brightest in the South.

When deciding what will actually occur in 1975, it must be remembered that the model is frictionless. It is not equipped to handle many subjective and unquantifiable factors which make industrial migration sluggish. For example, businessmen are not motivated to squeeze the last penny of excess profit out of the system. Competition and product homogeneity are far from perfect, as is knowledge. Time, effort, and money are required to gain sufficient information to build a plywood plant in a new location and arrange for the distribution of its output. Neither the cost of information nor the cost of risk and uncertainty were included in the model.

Timber procurement is another major economic activity that the model does not take into account. If purchase of forest land is considered necessary to assure a timber supply in the South, investments are substantially increased. Where a timber supply cannot be assured by purchase of land or long-term commitments, many firms may shrink from assuming that the multitude of small landowners in the South can be counted on to supply suitable stumpage.

In spite of the many qualifications, the model's results do indicate future changes in the plywood industry's location. Even according to the conservative solution, the plywood industry's incentive for locational change will be completely eliminated only when 36 percent of the industry has shifted to the South.

The speed with which industry reacts to the South's potential depends on industrial motivations which are hard to quantify, but there is plenty of room for optimism. Most plywood plants have

been built in the South by large, fully integrated, forest products companies with western experience in plywood manufacture. Virtually all of the firms either own or are closely associated with national wholesalers of building materials. The new plants, therefore, have readymade outlets through which to move southern pine plywood.

Thus far, most plants have been built only after a supply of timber had been obtained in a choice locality through purchase, merger, or long-term lease. As expansion continues, opportunities to control timber will diminish. Nevertheless, the momentum gathered over the last 5 years should continue. By 1975, the South should be producing at least 6 billion square feet of plywood—30 percent of the Nation's projected requirement.

LITERATURE CITED

1. American Plywood Association.
   1966. Geographical analysis of plywood shipments, Fourth Quarter 1966. Amer. Plywood Assoc., Tacoma, Wash.
2. Fedkiw, J.
   1964. Forest industry capacity, production, and available log supplies in the Douglas-fir subregion. USDA Forest Serv. Res. Pap. PNW-11, 63 pp. Pacific Northwest Forest and Range Exp. Sta., Portland, Oreg.
3. Hair, D., and Ulrich, A. H.
   1967. The demand and price situation for forest products, 1967. USDA Misc. Pub. 1066, 72 pp.
4. Haskell, H. H., Bair, W. M., and Donaldson, W.
   1966. Progress and problems in the southern pine plywood industry. Forest Prod. J. 16(4): 19-24.
5. Hoover, E. M.
   1948. The location of economic activity. 310 pp. N. Y.: McGraw-Hill Book Co.
6. Interstate Commerce Commission.
   1966. Carload waybill statistics, 1964: Territorial distribution traffic and revenue by commodity classes. Interstate Com. Comm., Bur. Econ. Statement TD-1, 117 pp. Wash., D. C.
7. King, R. A., and Henry, W. R.
   1959. Transportation models in studies of interregional competition. J. Farm Econ. 41: 997-1011.

8. Lambert, H. G.
1968. Plywood production marked time in 1967. Forest Ind. 95(1): 40-42.

9. Phelps, R. B.
1966. Wood products used in single-family houses inspected by the Federal Housing Administration, 1959 and 1962. USDA Statist. Bull. 366, 32 pp.

10. Rand McNally and Company.
1965. New cosmopolitan world atlas. 248 pp. Chicago: Rand McNally and Co.

11. Rand McNally and Company.
1968. Commercial atlas and marketing guide. Edition 99, 538 pp. Chicago: Rand McNally and Co.

12. Scott, R. C.
1966. Explode labor's false hopes for a bigger slice of pie. Woodworking Dig. 68(4): 18-19.

13. Sherman, D. F.
1967. Plywood weathers rough '66 yet scores notable gains. Forest Ind. 94(1): 42-45.

14. Smith, R. C., and Gedney, D. R.
1965. Manpower use in the wood-products industries of Oregon and Washington, 1950-1963. USDA Forest Serv. Res. Pap. PNW-28, 48 pp. Pacific Northwest Forest and Range Exp. Sta., Portland, Oreg.

15. U. S. Bureau of Labor Statistics.
1967. Employment and earnings statistics for States and areas, 1939-66. U. S. Bur. Labor Statist. Bull. 1370-4, 812 pp.

16. USDA Forest Products Laboratory.
1955. Wood handbook. USDA Agr. Handbook 72, 528 pp.

17. USDA Forest Service.
1965. Timber trends in the United States. USDA Forest Resource Rep. 17, 235 pp.

18. U. S. Department of Commerce.
1967. Lumber production and mill stocks, 1965. U. S. Dep. Comm., Bur. Census Curr. Ind. Rep. Ser. MA-24T(65)-1, 7 pp.

19. U. S. Department of Commerce.
1968. Lumber production and mill stocks, 1966. U. S. Dep. Comm., Bur. Census Curr. Ind. Rep. Ser. MA-24T(66)-1, 7 pp.

20. U. S. Senate.
1968. Log-exporting problems. I. Hearings before the Subcommittee on Retailing, Distribution, and Marketing Practices of the Select Committee on Small Business, United States Senate, 517 pp. U. S. Congr., 90th, 2d sess.

21. Van Hooser, D. D., and Christopher, J. F.
1967. Southern pulpwood production, 1966. USDA Forest Serv. Resource Bull. SO-9, 23 pp. Southern Forest Exp. Sta., New Orleans, La.

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Pine Sawtimber Price Behavior in South Carolina

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U. S. DEPARTMENT OF AGRICULTURE

1969

Pine Sawtimber Price Behavior in South Carolina

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This paper reports a study of factors that determine the prices paid for pine sawtimber stumpage in South Carolina. A further objective of the research was to describe long-term movements and short-term fluctuations in prices. The resulting information can be used in selling or buying timber, making decisions about timber-growing investments, or assigning values to timber for other purposes.

The prices analyzed were those paid to individual private owners between 1948 and 1967. The research extended earlier studies of the effects on prices of timber characteristics, market features, geographic location, and other factors *(1, 2, 3)*. Results are based on a greater number of transactions, over a longer span of time (20 years), than were available previously. Studies elsewhere in the South, especially those by Guttenberg and others of sales on national forests *(4, 5, 6)* were of value in the analysis.

The Data

Information was drawn from sales records that State foresters had submitted to the South Carolina Forestry Commission between January 1948 and December 1967. Marking timber stands for cutting is one of the services State foresters provide private landowners. Of the pine sawtimber sales made during this period, 747 qualified for study. Less than 10 percent of their volume was in hardwoods, and the date of sale and price received were recorded. The data also included total volume sold, number of trees marked, and acreage. Number of bidders was available for 373 sales.

The means and ranges of values for the major items of data were:

	Mean	Range
Bidders (number)	3	1-11
Tract area (acres)	47	1-350
Total volume (thousand board feet)	97	3-715
Volume per acre (thousand board feet)	3	1-15
Volume per tree (board feet)	151	40-520

Although the sales reports had been made primarily for administrative purposes, they were particularly well suited to price analysis. They represented a large number of similar sales distributed throughout the State. All of the timber sold was from lands of farmers and other individual private owners; none of the sales were from industrial or public lands. Moreover, all tracts had been marked by a single agency. Hence the marking practices and standards, and the kind of information collected and the form in which it was recorded, were uniform for all sales.

The prices are indicative of what such timber should bring, since the tracts had been sold in the manner foresters usually prescribe. Trees had been marked and cruised by an experienced individual, and the owners had sought several bids. Both buyers and sellers knew the volume of timber being offered for sale.

Price Movements

Between 1948 and 1967, the trend of pine sawtimber prices was upward (fig. 1). Over this period, the average price per thousand board feet, Scribner log rule, increased from $26.03 to $42.33. The rate of increase was 82 cents per year; in terms of compound interest, it amounted to a rise of 2½ percent yearly.

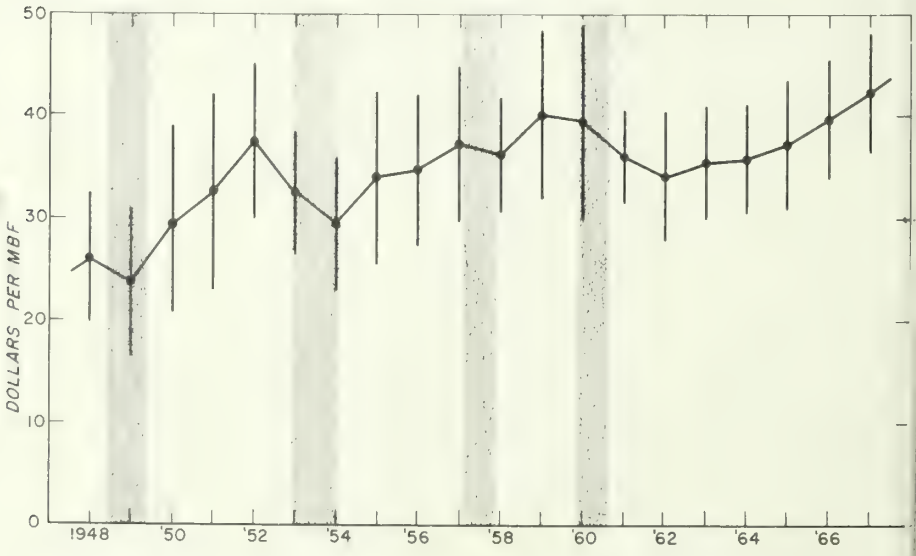

Figure 1.—*Annual average pine sawtimber prices and standard deviations, South Carolina, 1948-1967. Shaded areas represent recession periods as determined by the National Bureau of Economic Research.*

Average annual prices fluctuated widely around this trend. Peaks occurred in 1948, 1952, and 1959, and by the close of 1967 prices were rising toward a new high. The price pattern was fairly uniform over the State (table 1). Throughout each cycle, increases were more prolonged than declines. Both the trend and the cyclical variations around it were associated with the ups and downs of the lumber market.

Table 1.—*Average annual pine sawtimber prices per thousand board feet, by zone (see fig. 4). South Carolina, 1948-1967*

Year	Zone 1		Zone 2		Zone 3		Zone 4		Zone 5	
	Average price	Sales	Average price	Sales	Average price	Sales	Average price	Sales	Average price	Sales
	Dollars	*No.*	*Dollars*	*No.*	*Dollars*	*No.*	*Dollars*	*No.*	*Dollars*	*No.*
1948	24.81	7	22.51	7	26.42	8	26.65	11	31.78	4
1949	19.33	11	18.06	3	24.50	12	29.06	5	26.79	12
1950	28.07	8	25.30	12	34.14	14	28.15	6	29.53	14
1951	27.20	30	34.63	9	40.05	11	39.45	10	32.89	8
1952	32.21	17	36.59	10	39.20	5	40.38	6	43.10	12
1953	20.38	31	32.85	2	43.13	3	34.32	5	33.81	6
1954	23.42	11	32.08	8	32.30	1	34.70	6	31.07	6
1955	29.16	17	32.01	12	40.85	4	37.51	15	35.80	15
1956	28.60	5	40.05	4	45.00	1	33.90	3	35.95	4
1957	31.96	5	30.80	4	32.53	3	41.47	14	40.00	3
1958	30.66	8	34.06	7	38.97	7	39.25	12	36.25	2
1959	37.01	14	36.60	9	42.65	11	49.15	6	38.96	7
1960	37.47	17	46.62	4	38.98	17	45.23	6	34.35	4
1961	33.43	3	34.33	3	36.89	7	39.12	4	33.50	2
1962	30.97	11	34.00	4	54.30	1	40.60	2	36.00	2
1963	32.43	3	39.92	5	34.20	5	32.50	1	33.96	5
1964	32.18	5	37.90	5	37.08	12	41.10	2	32.28	5
1965	34.29	15	32.23	7	40.25	6	43.40	11	30.80	1
1966	39.56	5	37.36	7	41.86	5	40.67	3	41.43	3
1967	37.70	1	35.43	3	42.40	5	45.54	11	40.26	5
Total										
747		224		126		138		139		120

Within years, stumpage prices displayed seasonal patterns. The seasonal variation from 1948 to 1957 and from 1958 to 1967 was calculated by the moving-average method. Seasonal fluctuations in these two 10-year periods had approximately the same amplitude of movement, but in the first period prices peaked in the fall and in the second they peaked in late winter (fig. 2). On a scale in which the monthly average for the year equalled 100, the October price index was 109 for 1948-1957 and the February index was 107 for 1958-1967.

The shift in seasonal patterns between the first and second periods can be explained by a major change in the lumber industry. In the first period, the bulk of the lumber was cut by small, portable sawmills owned and operated by farmers. The high fall price for stumpage coincided with a slack time in farming operations—and

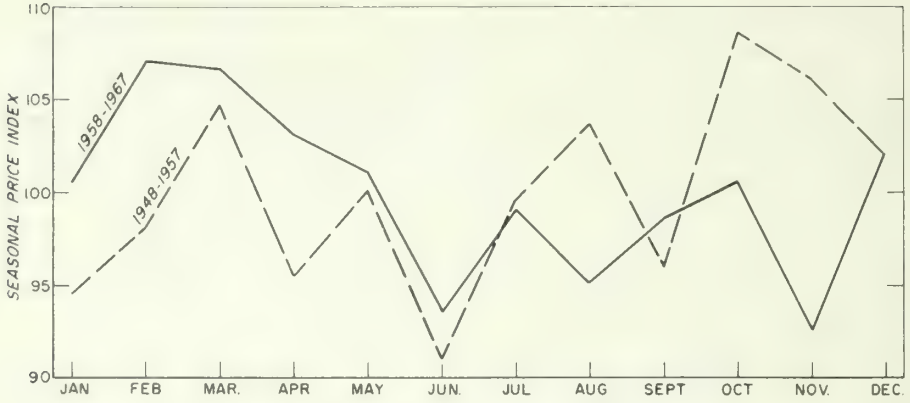

Figure 2.—*Average seasonal variation in pine sawtimber prices for two 10-year periods, 1948-1957 and 1958-1967, South Carolina.*

also with the driest weather and hence the best logging conditions. Further, at that time of year concentration yards, the main market for rough lumber sawn by these small mills, were building up their inventories. Hence, stumpage prices rose in conjunction with the buying activities of these mills.

By the second period, portable sawmills had all but disappeared and concentration yards with them. They were replaced by fewer, larger, more permanent sawmills operating the year around. Instead of carrying heavy inventories over the winter and into the spring, lumbermen bought and cut stumpage to fill orders. As lumber shipments increased in response to the sharp rise in housing starts that occurs throughout the East each spring, stumpage purchases also increased and prices rose accordingly.

Factors Influencing Values of Individual Tracts

Variables Tested

The variables to be tested as price determinants were, in the main, chosen for their relevance to the process through which buyers and sellers set a value on timber.

Traditionally, informed buyers and sellers have appraised standing timber on a residual-value basis. Standard appraisal procedures, such as the investment and overturn methods, incorporate this method of value determination. In making the calculations, estimated fixed and operating costs, plus an allowance for profit and risk, are deducted from the gross income that the product will bring. The margin that remains is stumpage value.

In determining the maximum price he can pay for stumpage, the buyer appraises timber in terms of his costs and returns. The seller, on the other hand, estimates his minimum price in terms of the probable costs and returns an average operator would experience. He proceeds in this way because the market is dominated by timber not grown under management. When timber from managed stands becomes abundant, the average total cost of growing a unit of timber will become the basis for establishing the seller's reserve price; but at present stumpage prices are unrelated to cost of production.

In addition to appraisal procedures, competition among buyers must be recognized as influencing timber prices. Where there is competition, the buyer must not only meet the seller's reserve price but must also offer more than all other bidders. Degree of competition is a function of the ratio between the number of buyers seeking timber and the number of forest owners offering timber for sale. It is indicated by the number of bidders for each tract.

The factors impelling buyer and seller towards a mutually acceptable price can be grouped as: Prices for forest products and other market factors; costs of logging trees, converting them into products, and delivering these to the market; competition among buyers and the availability of alternative tracts; and the level of sales knowledge and experience possessed by buyer and seller and their relative bargaining strengths. Some of these factors are quantifiable; others are not.

The principal functions expected of the variables chosen to estimate price were: First, to remove the temporal effects (both fluctuations and trends) and also the spatial effects from the price data. Then, to account for the behavior of the lumber market. Next, to recognize the factors that determine the residual value of the timber, such as the costs of harvesting and converting the trees to their final product and shipping to market, and the differential value of the lumber that could be cut from the trees. Finally, to indicate the degree of local competition for timber. Prior research *(2)* had made it possible to restrict the number of variables considered.

Fifteen factors were chosen as independent variables for testing as possible price determinants. Of these, five were obtained directly from sales records:

V = total volume sold (thousand board feet, Scribner log rule)

A = number of acres in sale area

T = number of trees sold

B = number of bidders making offers for the timber

D = date of sale (month in which timber was sold, numbered serially from January 1946 = 001).

Seven variables were generated from the primary data:

D^2 = sale date squared

V/A = average volume sold per acre

V/T = average volume per tree sold

T/A = average number of trees sold per acre

V × V/A = interaction between total volume and volume per acre

V/T × V/A = interaction between volume per tree and volume per acre

V/A × T/A = interaction between volume per acre and trees per acre.

The remaining factors were:

L = location of sale (county seat for county in which sale took place, in terms of distance and direction to State capital)

P_L = Bureau of Labor Statistics (BLS) average wholesale price per thousand board feet, lumber tally, of southern pine No. 2 dimension lumber

VP_L = Twelve-month change in BLS average price of southern pine No. 2 dimension lumber to the month prior to the timber sale.

Locations of sales were measured on an arbitrary grid superimposed on the State. East-west and north-south coordinates were spaced at 10-mile intervals, and the zero coordinates passed through Columbia, the State capital, at the point where latitude 34°00′ N. and longitude 81°00′ W. intersect. Since the records located the sales only by county, the county seats were arbitrarily taken as the places of sale. The geographic relations of the seats to the capital were measured on the grid—positively to the north and east, and negatively to the south and west. Negative values were then eliminated by adding a constant of 200 miles to all readings.

Estimating Equations

Three related statistical-economic models were set up to identify the price determinants. Stumpage price, which was taken directly from the sales records, was the dependent variable in two of the models. It was identified as P_S = southern pine sawtimber price (dollars per thousand board feet, Scribner rule). These two models differed only in that one included the number of bidders as an independent variable. In the third model, number of bidders was the dependent variable.

The models were all of the single-equation form:

Price Model I

P_S : V, T, A, B, D, D^2, V/T, V/A, T/A, V $\times$ V/A, V/T $\times$ V/A, V/A $\times$ T/A, L, P_L, VP_L

Price Model II

Price Model I with number of bidders (B) excluded

Competition Model

B : V, T, A, D, D^2, V/T, V/A, T/A, V $\times$ V/A, V/T $\times$ V/A, V/A $\times$ T/A, L, P_L, VP_L

The multiple regression equation for each model was fitted in stepwise procedure by the method of least squares. The analysis showed that seven of the 15 variables were significant (0.05 level) in price equation I, nine of the 14 in price equation II, and five of the 14 in the competition equation. The regression coefficients and constants follow:

	Price equation I	Price equation II	Competition equation
Total volume			0.00576
Volume/acres		0.36545	.06276
Volume $\times$ volume/acres		.00194	
Volume/tree	41.08726	45.09411	
$\frac{\text{Volume}}{\text{trees}} \times \frac{\text{volume}}{\text{acres}}$	—.62198	—1.68615	
Bidders	1.23129		
Location	.00202	.00211	.00040
Lumber price	.74701	.85935	
Lumber price change	—.21760	—.25293	
Date			—.00804
$Date^2$		—.00008	
Constant	—38.41731	—43.54423	2.63746

The coefficients of multiple determination (R^2) and the standard errors of estimate (SE) for the three equations, together with the means ($\overline{Y}$) of the dependent variables, are:

Equation	R^2	$\overline{Y}$	SE
Price I	0.47	$36.92	$5.95
Price II	.44	$36.92	$6.12
Competition	.24	2.89 bids	1.54 bids

Factors Related to Price

Adjustments for lumber prices and changes in the prices removed much of the effect of temporal variation from the data in the two

price equations. And spatial variation was largely eliminated by adjustments for the location of the sale.

Stumpage prices followed about the same pattern over time as did lumber prices (fig. 3), but fluctuated more (as would be expected of a raw material).

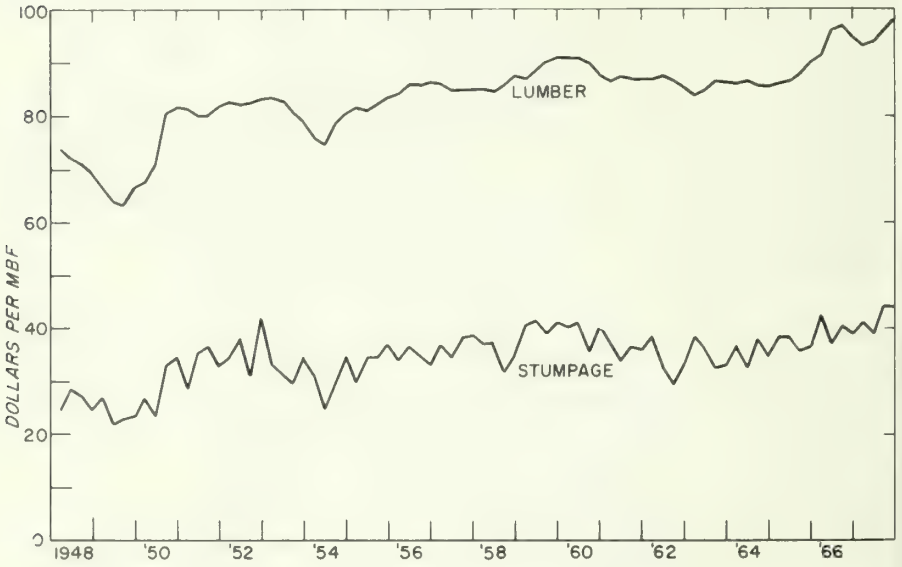

Figure 3.—*Quarterly average prices paid for pine sawtimber stumpage in South Carolina and BLS quarterly average wholesale prices for southern pine No. 2 dimension lumber, 1948-1967.*

The net effect of lumber market activity on stumpage price is indicated by the regression coefficients in the two price equations. For each dollar advance in the lumber price level, stumpage rose 75 to 86 cents. The effect was dampened by the direction and magnitude of the change in lumber price from the previous year. The two lumber price variables must be taken together in evaluating the market's influence on stumpage.

Even within this single State, stumpage prices varied geographically. South Carolina is shaped roughly like an inverted triangle (fig. 4). In general, prices were lowest in the northwest corner (Zone 1)—Piedmont—and highest in the northeast corner (Zone 4)—northern Coastal Plain. The positive coefficients for the location coordinates obtained in the price equations indicate that prices tended to rise across the State toward the east and south. Price variations over his limited area reflect differences in forest resources, logging conditions, and markets.

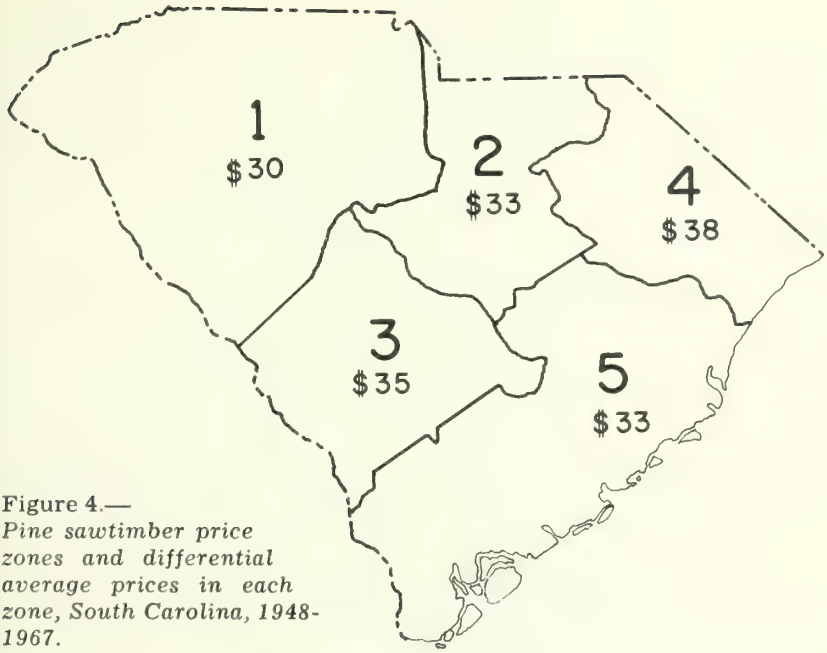

Figure 4.—
Pine sawtimber price zones and differential average prices in each zone, South Carolina, 1948-1967.

When the effect of temporal and spatial variation had been removed from the data for price equation I, then volume per tree, the interaction of volume per tree and volume per acre, and number of bidders determined the price paid for the timber. The net effect of each variable was examined by holding the other variables constant at their means.

Tree size, measured in terms of volume per tree, affects harvesting costs. Logging studies have shown that it costs less per thousand board feet to harvest a large tree than a small one. Since stumpage price is a residual value, i. e., lumber price minus costs, increases in tree size should influence stumpage price by lowering costs. For southern pine, tree size is also a principal indicator of tree quality. Large trees yield high-value lumber. In the presence of the variables included in the equation, an increase of 100 board feet in the average volume per tree increased the price of stumpage about $4 per thousand board feet (fig. 5).

As expected, competition for timber exerted a strong influence. Stumpage price increased $1.23 per thousand board feet with each additional bidder (fig. 5).

When number of bidders was excluded as a price determinant, all of the variables in price equation I reappeared in price equation II. Their coefficients had the same signs and strikingly similar magnatudes.

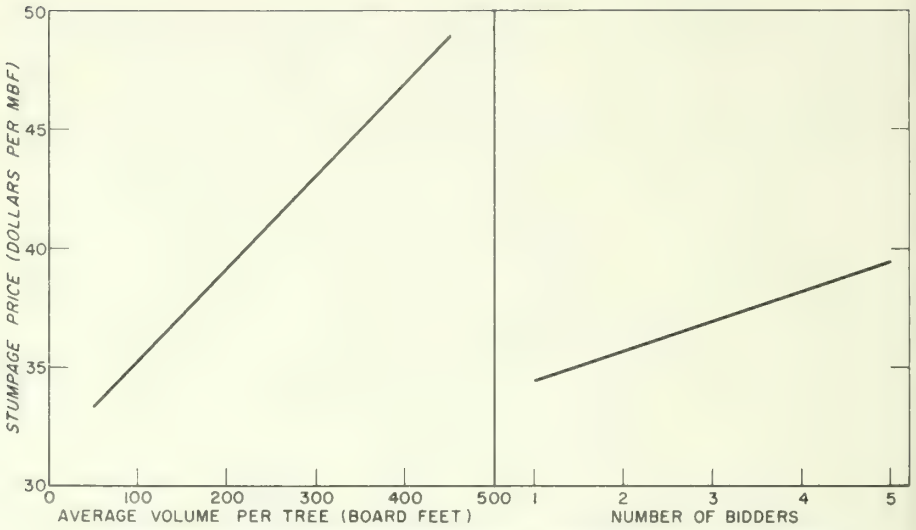

Figure 5.—*Price for pine sawtimber stumpage increases with tree size and degree of competition.*

Three new variables appeared in price equation II. They were average volume per acre, total volume times average volume per acre, and date of sale squared. The first two are cost factors; the last is a time element.

When average volume per acre appeared in price equation I as an interaction with average volume per tree, it had a negative coefficient. The sign for this variable was the same in price equation II. But when volume per acre appeared by itself and as an interaction with total volume, the regression coefficients for these two variables were positive. The net effect of an increase in average volume per acre was to increase stumpage price. The positive relationship of volume per acre to stumpage price agrees with findings in previous studies *(3, 4)*.

The total volume of timber offered for sale had a positive but trivial influence on stumpage price through its interaction with average volume per acre. The variable contributes something to precision, especially where volume per acre is high.

Sale date squared had a negative coefficient in price equation II. This indicates that stumpage prices declined slowly over the 20-year period. The net effect of this variable was hidden by a rising lumber market.

It was hypothesized that the three variables appearing when bids were deleted were the determinants of bids. The hypothesis was tested by using the competition equation; and, while the coefficient of multiple determination was only 24 percent, the results were

positive. All of the additional variables in price equation II appeared in the competition equation, although not in exactly the same form. Total volume of timber sold was in both equations, as was average volume per acre. In the price equation, these variables appeared as an interaction; in the competition equation they had additive effects. Both variables would affect the number of bidders through their effect on the profitability of harvesting.

Date of sale assumed a linear form in the price equation but a quadratic form in the competition equation. The negative coefficient in the competition equation indicated that declining stumpage prices over time were the result of a lessening number of bidders.

Coordinates of sale location appeared in all three equations. The inference is that stumpage price was influenced directly by the geographic structure of prices and also through differences in the degree of local competition for timber.

Discussion and Conclusions

The estimating equation based on price model I, which included number of bidders, was the simplest since it contained the fewest independent variables. It also had a lower standard error of estimate than the other price equation and explained more of the variation. The equation is consistent with our theoretical understanding of price-making factors, and with earlier research. It shows that sawtimber price is influenced by harvesting costs, changes in the lumber market, degree of local competition for timber, and geographic structure of timber prices.

Equations I and II explained nearly half of the price variation. Sources of unexplained variation seem reasonably clear, though difficult to cope with. First, the adjustments for temporal and spatial effects were not completely effective. Wholesale lumber prices were imperfect deflators of stumpage price to one point in time, even when date of sale was included in the equation. And, while it was pragmatically known that prices varied across the State, the pattern was undefined. Since the number of sales is limited in both time and place, the researcher faces a dilemma: If he collects cross-sectional data to eliminate the time effect, he enlarges the spatial error; on the other hand, a sample independent of time probably could be obtained only from an area that might include several States.

Other sources of unexplained variation are factors that were measured imprecisely or not at all. Among these were location of sales within counties, distance from tract to nearest sawmill, condition of road, and difficulty of the logging chance. Finally, considerable

variation probably arises from human factors that cannot readil be measured—e.g., the buyer's need to replenish his log inventory the seller's need for money and his knowledge of timber values, an the bargaining skills of both parties.

Although price equation I is more useful for describing pric formulation, price equation II is superior for purposes of predictio because it contains only variables that are known prior to time o sale. Furthermore, the forest manager has some of these variable under his control.

Obviously, he cannot control the location of the timber, but h can often decide to some extent the time of year when he sells an the general position of the cyclical price curves. In marking timbe he can increase the total volume he offers for sale, the average volum per acre, and the volume of the average tree. Frequently some o these marking objectives are in conflict. Price equation II indicate that, where the seller has a choice between selling larger trees an selling more volume by making heavier cuts per acre, it is better t aim for volume per tree.

Literature Cited

1. Anderson, W. C.
   1957. Sawtimber prices are highest in the fall. USDA Fores Serv. Southeast. Forest Exp. Sta. Res. Note 105, 1 p.
2. Anderson, W. C.
   1961. A method of appraising pine sawtimber in South Caro lina. USDA Forest Serv. Southeast. Forest Exp. Sta. Sta. Pap. 122, 15 pp.
3. Cruikshank, J. W., and Anderson, W. C.
   1955. Pine sawtimber stumpage prices in South Carolina 1948-1954. USDA Forest Serv. Southeast. Forest Exp Sta., Sta. Pap. 57, 14 pp.
4. Guttenberg, S.
   1956. Influence of timber characteristics upon stumpag prices. USDA Forest Serv. Southern Forest Exp. Sta Occas. Pap. 146, 14 pp.
5. Guttenberg, S., and Fasick, C. A.
   1965. What decides southern pine stumpage prices? Fores Ind. 92(13): 46-47.
6. Guttenberg, S., and Row, C.
   1961. Markets, timber quality influence southern pine stump age prices. Timberman 62(10): 66-67, 69.

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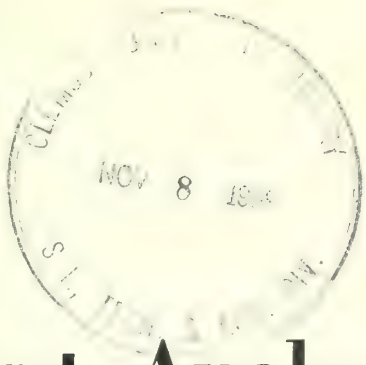

Input-Output Analysis of the Southern Forest Economy, 1963

Harold F. Kaiser, Jr.

SOUTHERN FOREST EXPERIMENT STATION
FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

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Appendix 17

INPUT-OUTPUT ANALYSIS OF THE SOUTHERN FOREST ECONOMY, 1963

Harold F. Kaiser, Jr.

An input-output model is developed to show the flow of goods through the southern forest economy. Analysis of unpublished data from the 1963 Census of Manufactures indicates that primary processing industries produced $5,126 million worth of output while purchasing stumpage costing $335 million. Secondary processing industries converted a portion of this output into products worth $3,365 million. Collectively, forest-related industries paid $2,181 million in wages to southerners.

Input-output analysis can show the contribution of a region's forests to its income and employment. Estimates so derived can help identify Federal, State, and local interest in potential forest investments, as well as the appropriate level and form of economic incentives. Previously published input-output tables are of limited value for southern forests because forestry is usually merged with agriculture and fisheries, and the scope is either national or for regions outside the South. This paper presents a forestry-oriented model implemented with data from the 1963 Census of Manufactures.

Input-output tables show the purchases of each sector of the economy from all other sectors and account for the sales of each sector to all others. The analysis is analogous to double-entry bookkeeping. Outputs from one industry are inputs for others.

This form of analysis was originated by Francois Quesnay in 1758 in his *Tableau Economique,* which stressed the interdependence of farm activities *(10)*. Later, Wassily Leontief developed a modern operational theory of production based on economic interdependence. In 1941, he published the first empirical input-output study of the American economy *(9)*.

Tables for the American economy were developed by the U. S. Bureau of Labor Statistics for 1947 and by the U. S. Department of Commerce, Office of Business Economics, National Economics Division, for 1958. Recently, input-output studies were made in Clinton County, Pennsylvania *(6, 7)*, and in the States of Utah *(3)*, Washington *(2)*, and Mississippi *(5)*.

CASH-FLOW MATRIX

The data analyzed in this paper come primarily from previously unpublished regional tabulations from the Census of Manufactures. These statistics are categorized according to the Standard Industrial Classification (SIC) *(4)*. In this system, reporting units are establishments rather than legal entities or companies, and each establishment is classed according to its major activity. In most instances the establishments are at a single location and are predominantly engaged in only one economic activity. Where a single location encompasses two or more distinct and separate activities, such activities are treated as separate establishments. Production from establishments engaged in similar activities is aggregated until a sufficient value is obtained to form an industry, the basic unit of analysis.

The SIC industries selected for the southern model are those that process logs and bolts and those that utilize the wood products of these primary processors. Thirty-one industries ranging from logging contractors to manufacturers of sanitary food containers were included. The industries are in the SIC groups for lumber and wood products (SIC 24), furniture and fixtures (SIC 25), and paper and allied products (SIC 26). Products manufactured by these industries range from such major items as lumber and kraft paper to such minor items as clothespins and toothpicks.

From the selected industries, 28 selling and purchasing classes were formed for the southern-forest-products model. These classes are defined in the appendix. The major modification of the SIC classification was in the sawmill and planing-mill category, where several industries were combined. Production from the special-sawmill and hardwood-dimension industries was combined with production from the sawmill and planing-mill industry. Special-sawmill output was merged because of its relatively low sales volume, and hardwood dimension was merged because over half of the furniture dimension production could not be accounted for by recorded purchases. This underidentification probably arose from differences between sawmills' and furniture manufactures' classifications for dimension stock.

Manufacturers of wirebound boxes and crates were merged with producers of veneer and plywood containers because of the low sales volumes involved. Production from pulpmills was combined with that of papermills to avoid disclosure of the output of individual firms. The final modification was the division of logging contractors into harvesters of sawtimber and veneer logs and harvesters of pulpwood.

A special feature of the model is the inclusion of softwood and hardwood stumpage-input classes. Data from U. S. Department of Agriculture, Forest Service,[1] was used to divide Census stumpage values into hardwood and softwood categories. The selling sectors of sawmills and planing mills and veneer and plywood plants were divided into softwood and hardwood categories on the basis of price information from the 1963 Census of Manufactures *(13)* and the Department of Labor *(15)*. To include these selling categories required the construction of a rectangular industrial matrix.

Sectors were added to the model to permit complete analysis of cash flows through the forest products economy. Additional selling categories include employment, capital expenditures, and other inputs. Purchasing categories added include manufacturing and transportation, construction and maintenance, and final consumer. Inclusion of the additional selling and purchasing sectors allows double-entry bookkeeping to be established for the various product sectors.

INVERSION OF THE MATRIX

A table was constructed to depict direct and indirect effects of changes in final demand. This table shows how the outputs in the immediate supplying industries and all related industries expand when one industry's demand is increased by one exogenous dollar. This dollar might come from households, investors, foreign buyers, government agencies, or any other buyer included in the final-demand sectors. If the final demand for industry A increases by $1, for example, there will be direct increases in purchases from A's supplying industries, B and C. In addition, when industry B sells more of its output to industry A, B needs more products from its own supplying industries. The process continues throughout the economy. Thus, the effects are analogous to ever-widening circles of ripples which occur when a stone is thrown into a pond.

Although a power series can be used to approximate the magnitude of direct and indirect effects, a precise value can be found through inversion of the Leontief matrix by electronic computer. The Leontief matrix is the difference between an identity matrix and the direct-coefficient matrix. By direct coefficients, we mean the percentages of an industry's total cost attributed to each of its supply industries. To invert the matrix of the forest industries, the rectangular matrix had to be converted to a square format. Two columns of zeros were added to the left side of the forest products matrix for the stumpage sectors. Since stumpage sectors do not purchase from other forest products industries, the entering of zeros does

[1] USDA Forest Service. Average stumpage values—sold volume (per MBF)—sawtimber and pulpwood. Reg. 8 Rep. Atlanta, Ga. 1968.

not influence the results. The columns for sawmills and planing mills and veneer and plywood plants were divided into softwood and hardwood categories on the basis of the value of production. A FORTRAN IV program for finding the direct and indirect effects of changes in demand is available on request from the Southern Forest Experiment Station.

CRITIQUE OF THE MODEL

The model is designed to organize a large amount of data to show the production and distribution characteristics of individual forest industries and the interrelationships that bind the industries together. Thus, it is an instrument to exhibit and analyze the economy.

The chief problems with the model are associated with data requirements. Since collection of field data is both costly and time consuming, implementation of the model depends upon information from standard statistical sources. The use of these data creates problems, however. One problem arose when purchases of a product exceeded reported output. This underidentification was most severe in the logging sectors, where the Census had not fully taken into account the output of both sawtimber and pulpwood producers. For sawtimber contractors, values were adjusted upward in proportion to the cost distribution found in the Census. Estimates for pulpwood producers were based on the assumptions that the workers in 1963 harvested 1.50 cords of softwood and 1.25 cords of hardwood per man-day and were paid $1.15 per hour.

Another problem was that the 1963 Census often aggregated forest products that ideally should have remained separate. One example occurred in the class for other wood products (SIC 2499), where composition board was aggregated with wooden pallets and skids. Overaggregation reduces the descriptive value of the model and can lead to serious errors in forecasting.

The last major problem caused by data from standard statistical sources is that created by forest products shipped into the South. Shipments could be easily handled by the addition of an import row in the cash flow matrix. However, the information concerning shipments from other regions and foreign countries to the South is inadequate. The primary source of statistics is the *1963 Census of Transportation (14)*, where the shipment patterns are shown for broad commodity groups. While these data were sufficient for rough estimates of the percentages of products consumed regionally and shipped to other regions, they were inadequate for import estimates. Abandonment of the import sector created some overestimates of the contribution of southern wood products to local industries.

Several simplifying assumptions are inherent in the model: (1) The economic system is in equilibrium at the given price level. (2) Each industry makes a unique set of products. (3) Production functions are linear and homogeneous, and the factors of production are utilized in fixed proportions. Although these assumptions do not limit the present analysis, they affect the development of parameters for altering the model over time. For instance, the direct coefficients are based on assumption (3), which rules out both internal and external economies and diseconomies of scale. Furthermore, it does not allow for relative price changes over time. Thus, the coefficients are not responsive to conditions that are likely to cause important changes in the economy.

RESULTS

The South produced more timber products in the past century than any other section of the United States *(12)*. The forest resource and its dependent wood-using industries continue to contribute greatly to the southern economy. In terms of value added by manufacturing in 1963,[2] paper and allied products ranked seventh among southern industrial groups (fig. 1). Lumber and wood products ranked 15th, and furniture and fixtures, 16th. Overall, these three industrial groups accounted for about $1 of every $9.50 added by manufacturing in the South. They paid $1 of every $3.50 to industrial employees.

[2] Value added by manufacturing is derived by subtracting the total cost of materials (including supplies, fuel, electric energy, cost of resales, and miscellaneous receipts) from the value of shipments (including resales) and other receipts, and adding the net changes in finished products and work-in-process inventories between the beginning and end of the year.

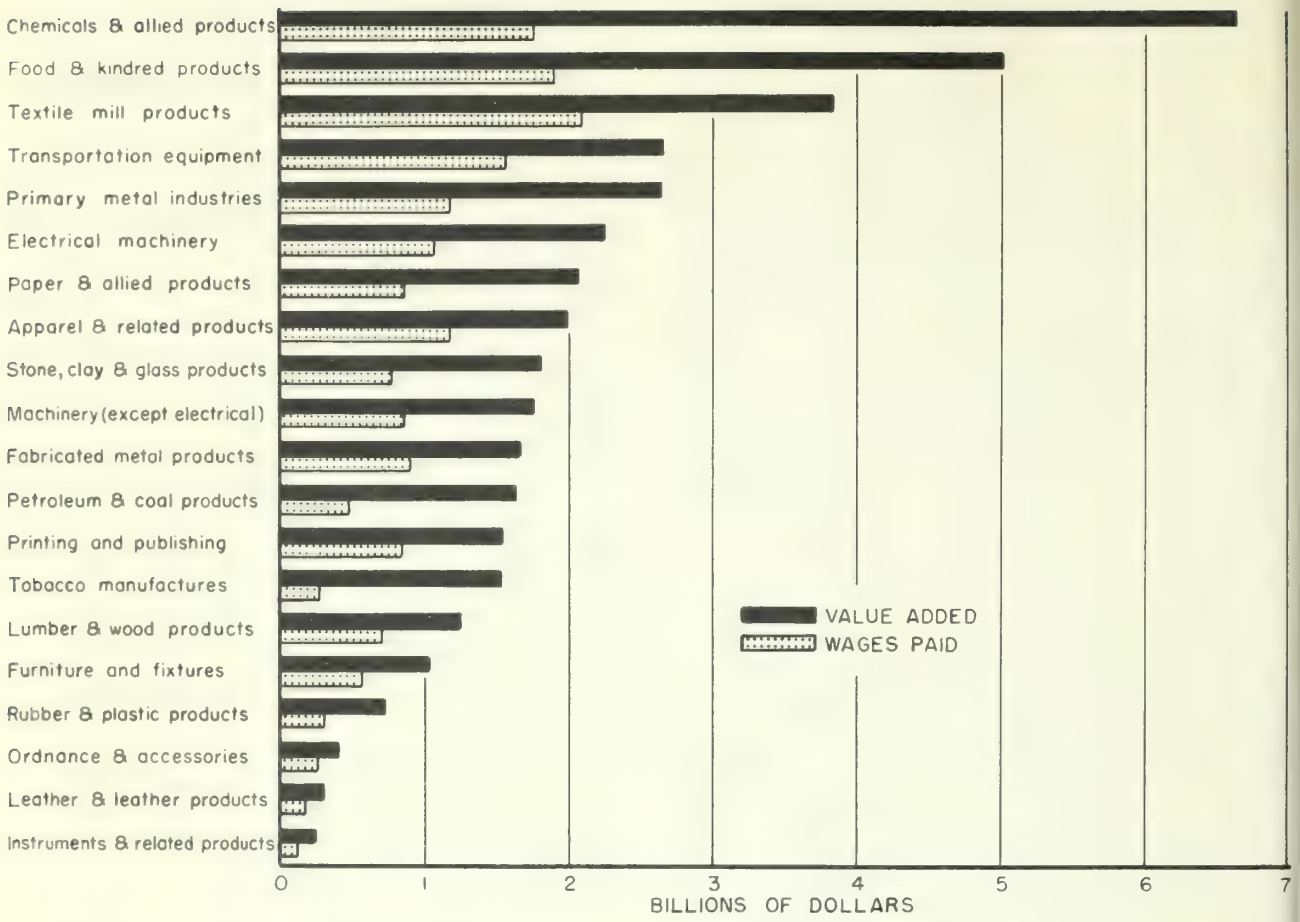

Figure 1.—*Value added and wages paid by southern industry groups, 1963.*

Table 1 shows the cash flows among the wood-using industries contained within these three industrial groups. Here are found the 1963 dollar flows of goods between the South's forests and final-demand sectors. Selling sectors include the forest products input industries (table 1, rows 1-32) plus categories of employment, capital expenditures, and other inputs. Stumpage, sawmills and planing mills, and veneer and plywood industries are subdivided into hardwood and softwood classes. Buying sectors include the forest industries (table 1, columns A-BB), as well as final-demand sectors (table 1, columns CC-HH). Census statistics *(13, 14)* together with information from the U. S. Department of Agriculture *(8)* and *Lockwood's Directory of Paper and Allied Trades (11)* were used to divide output among final-demand sectors. The Census of Transportation provides regional information for commodity groups only; thus, the figures on shipments within the South and to other regions have been deduced from national patterns for individual industries.

By reading down any column in table 1, one learns how much a forest products industry or final-demand sector purchased from each selling sector. Similarly, each row shows where an industry's output went. For example, reading down column P for paper- and pulpmills reveals that this sector purchased $182.7 million of pulpwood from producers, $3.6 million of hardwood chips and $26.5 million of softwood chips from sawmills and planing mills, and $39.5 million of pulp from other mills. Moreover, paper- and pulpmills paid their employees $258.6 million and made new capital expenditures of $84.7 million, while other inputs totaled $620.3 million. The gross outlay was $1,215.9 million. On the output side, row 20 shows that paper- and pulpmills had sales of $39.5 million to other papermills, $25.2 million to paperboard mills, $0.5 million to building-paper and board mills, and $27.1 million

Table 2.—*Total direct production requirements per dollar of output, southern forest products economy, 196*

		Logging contractors	Pulpwood producers	Sawmills and planing mills	Veneer and plywood mills	Millwork plants	Prefabricated wood products	Nailed wooden boxes	Other wooden containers	F
		A	B	C	D	E	F	G	H	
Hardwood stumpage	(1)	0.1354	0.0165	0.0408	0.0113					
Softwood stumpage	(2)	.2164	.1666	.0700	.0004					
Logging contractors	(3)			.1243	.1667	0.0058	0.0089	0.0314	0.103	
Pulpwood producers	(4)									
Sawmills and planing, hardwood	(5)			.0966	.0199	.0505	.0129	.2338	.08(	
Sawmills and planing, softwood	(6)			.0618		.1751	.1786	.0904	.024	
Veneer and plywood, hardwood	(7)				.2300	.0860			.068	
Veneer and plywood, softwood	(8)				.0039	.0143	.0317	.0079		
Millwork plants	(9)									3
Prefabricated wood products	(10)									1
Nailed wooden boxes	(11)									1
Other wooden containers	(12)									7
Wood preserving	(13)									
Other wood products	(14)									
Nonupholstered wood furniture	(15)									
Upholstered wood furniture	(16)									
Wood office furniture	(17)									
Public building furniture	(18)									1
Wood partitions and fixtures	(19)									
Paper- and pulpmills, except building paper	(20)									2
Paperboard mills	(21)									
Building paper and board mills	(22)									
Paper coating and glazing	(23)									
Envelopes	(24)									
Bags, except textile	(25)									
Sanitary paper products	(26)									
Converted paper products	(27)									
Folding paperboard boxes	(28)									
Set-up paperboard boxes	(29)									
Corrugated shipping containers	(30)									
Sanitary food containers	(31)									
Fiber cans, tubes, and drums	(32)									4
Employment	(33)	.2481	.4041	.2564	.2573	.2294	.1964	.3084	.30(	4
Capital expenditures	(34)	.1010	.0782	.0626	.0381	.0164	.0208	.0216	.01	1
Other inputs	(35)	.2991	.3346	.2875	.2724	.4225	.5507	.3065	.40	3
Total	(36)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.00(	

Purchasing sector													Final demand					
													Manufacturing and transportation		Construction and maintenance		Final consumer	
Paper and pulpmills, except building paper	Paperboard mills	Building paper and board mills	Paper coating and glazing	Envelopes	Bags, except textile	Sanitary paper products	Converted paper products	Folding paperboard boxes	Set-up paperboard boxes	Corrugated shipping containers	Sanitary food containers	Fiber cans, tubes, and drums	South	Other regions	South	Other regions	South	Other regions	Total
P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE	FF	GG	HH	II
																			100.1
																			225.2
																			259.2
182.7	249.9	5 2																	447.7
3.6	3.0	.2											92.8	72.2	96.3	20.9			680.3
26.5	31.0	.8											26.6	4.9	327.8	59.4			669.0
													32.3	12.4					217.1
																			13.8
															240.7	52.2			292.9
															92.1	8.7			100.8
													34.4	16.5					50.9
													71.4	33.4					104 8
													10.9	5.2	90.7	44.5			151.3
													67.1	27 0	37.2	16.0	39.0	16.7	219.5
													53.8	32.8	84.9	51.7	459.5	279.3	962.0
													2.8				259.9	180.6	469.7
																	17.4	9.1	26.5
																	23.6	46.3	69 9
																	32.8	30.5	63.3
39.5	25.2	.5	27.1	16.9	237.1	38.4	21.9	3.3	1.7	3	1.1	1.2	618.5	183.2					1,215.9
			14.3		.4		2.4	78.0	11.2	271.4	76.3	13.5	12.6	817.5					1,297.6
															69.7	41.9			111.6
													67.0	81.9			3.0	3.5	155.4
																	40.5	11.4	51.9
													209.1	233.2					442.3
																	53.9	37.5	91.4
													17.2	2.9			45.1	31.5	96.7
													145.8	33.7					179.5
													29.0	6.7					35.7
													368.4	85.3					455.4
													142.7	33.3			12.7	4.2	192.9
													54.1	18.1					72.2
258.6	215.5	28.3	16 9	14.3	90.2	8.1	19.5	45.3	10.8	90.2	32.1	19.9							2,180.6
84.7	109.0	3.5	5.0	2.0	10.3	.8	1.6	5.1	1.2	12.5	11.6	3.6							492.2
620.3	664.0	73.1	92.1	18.7	104.3	44.1	51.3	47.8	10.8	81.0	71.8	34.0							3,731.3
,215.9	1,297.6	111.6	155.4	51.9	442.3	91.4	96.7	179.5	35.7	455.4	192.9	72.2	2,057.5	1,699.2	1,039.4	295.3	987.4	650.6	15,926.6

Table 1.—*Cash flow in the southern forest economy, 1963 (in millions of dollars)*

Selling sector [1]		Forest industries														
		Logging contractors	Pulpwood producers	Sawmills and planing mills	Veneer and plywood plants	Millwork plants	Prefabricated wood products	Nailed wooden boxes	Other wooden containers	Wood preserving	Other wood products	Nonupholstered wood furniture	Upholstered wood furniture	Wood office furniture	Public building furniture	Wood partitions and fixtures
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Hardwood stumpage	(1)	35.1	7.4	55.0	2.6											
Softwood stumpage	(2)	56.1	74.6	94.4	.1											
Logging contractors	(3)			167.7	38.5	1.7	0 9	1 6	10.3	38.0						
Pulpwood producers	(4)										9.9					
Sawmills and planing, hardwood	(5)			130.3	4.6	14.8	1.3	11.9	8.4	10.0	25.1	145.5	28.4	2.7	6.1	2.2
Sawmills and planing, softwood	(6)			83.4		51.3	18.0	4 6	2.6	12.1	10.0	7.1	1.3		.6	1.0
Veneer and plywood, hardwood	(7)				53.1	25.2			7.2			78.3		.9	3.0	4.7
Veneer and plywood, softwood	(8)				.9	4.2	3.2	.4				2.6			.5	2.0
Millwork plants	(9)															
Prefabricated wood products	(10)															
Nailed wooden boxes	(11)															
Other wooden containers	(12)															
Wood preserving	(13)															
Other wood products	(14)											12.7		.1	1.8	1.9
Nonupholstered wood furniture	(15)															
Upholstered wood furniture	(16)											1.9	24.5			
Wood office furniture	(17)															
Public building furniture	(18)															
Wood partitions and fixtures	(19)															
Paper- and pulpmills, except building paper	(20)															
Paperboard mills	(21)															
Building paper and board mills	(22)															
Paper coating and glazing	(23)															
Envelopes	(24)															
Bags, except textile	(25)															
Sanitary paper products	(26)															
Converted paper products	(27)															
Folding paperboard boxes	(28)															
Set-up paperboard boxes	(29)															
Corrugated shipping containers	(30)													.5	1.1	.1
Sanitary food containers	(31)															
Fiber cans, tubes, and drums	(32)															
Employment	(33)	64.3	180.9	345.9	59.4	67.2	19.8	15.7	32.3	26.9	63.9	277.0	128.4	6.8	20.8	21.6
Capital expenditures	(34)	26.2	35.0	84.5	8.8	4.8	2.1	1.1	1.4	3.6	11.9	41.1	17.3	.6	1.5	1.4
Other inputs	(35)	77.5	149.8	388.1	62.9	123.7	55.5	15.6	42.1	60.7	98.7	395.8	269.8	14.9	34.5	28.4
Total	(36)	259.2	447.7	1,349.3	230.9	292.9	100.8	50.9	104.8	151.3	219.5	962.0	469.7	26.5	69.9	63.3

[1] A complete description of all the forest product industries and their corresponding SIC numbers can be found in Appendix.

to paper coating and glazing establishments. The total sales equal the total outlay of $1,215.9 million, as the double-entry method requires.

General observations from table 1 are that industries relying heavily upon the South's forests contributed $2,180.6 million in wages to the southern economy and invested $492.2 million. Large contributors to regional prosperity included sawmills and planing mills, nonupholstered wood furniture plants, and paper, pulp, and paperboard mills.

A word of warning—the total product ($15,926.6 million) from the input-output table cannot be compared with the contribution of the southern forest economy to Gross National Product (GNP). In computing GNP, efforts are made to eliminate double counting, while input-output analysis deliberately compounds all intermediate transactions through which goods or services pass on the way to the final consumer. The difference is in objectives. In national income analysis the aim is to measure the final value of goods and services produced. Input-output analysis strives to account for all transactions to give insight into the structure and operation of the economy.

The statistics in table 1 have been converted to percentages in table 2 to depict the proportion of an industry's total cost attributable to each of its supplying industries. While table 1 can be totaled in two directions, table 2 values must be read down only. For example, by

	Wood preserving	Other wood products	Nonupholstered wood furniture	Upholstered wood furniture	Wood office furniture	Public building furniture	Wood partitions and fixtures	Paper- and pulpmills, except building paper	Paperboard mills	Building paper and board mills	Paper coating and glazing	Envelopes	Bags, except textile	Sanitary paper products	Converted paper products	Folding paperboard boxes	Set-up paperboard boxes	Corrugated shipping containers	Sanitary food containers	Fiber cans, tubes, and drums
	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB
1	0.2512																			
		0.0451						0.1503	0.1926	0.0466										
2	.0661	.1144	0.1512	0.0605	0.1019	0.0873	0.0348	.0030	.0023	.0018										
8	.0800	.0456	.0074	.0028		.0086	.0158	.0218	.0239	.0072										
7			.0814		.0339	.0429	.0742													
			.0027			.0072	.0316													
			.0132		.0038	.0258	.0300													
			.0020	.0522																
								.0325	.0194	.0045	0.1744	0.3256	0.5361	0.4201	0.2265	0.0184	0.0476	0.0007	0.0057	0.016
											.0920		.0009		.0248	.4345	.3137	.5960	.3955	.187
					.0189	.0157	.0016													
2	.1778	.2911	.2879	.2734	.2566	.2976	.3412	.2127	.1661	.2536	.1088	.2755	.2039	.0886	.2017	.2524	.3025	.1981	.1664	.275
4	.0238	.0542	.0427	.0368	.0226	.0215	.0221	.0697	.0840	.0314	.0322	.0385	.0233	.0088	.0165	.0284	.0336	.0274	.0601	.049
6	.4011	.4496	.4115	.5743	.5623	.4934	.4487	.5100	.5117	.6549	.5926	.3604	.2358	.4825	.5305	.2663	.3026	.1778	.3723	.470
0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.000

reading down column P, we find that, for each dollar of production, paper- and pulpmills pay $0.1503 to pulpwood producers, $0.0030 to hardwood sawmills, $0.0218 to softwood mills, and $0.0325 to other paper- and pulpmills. Also, paper- and pulpmills spend $0.2127 in wages, $0.0697 in capital expenditures, and $0.5100 for other inputs. A comparison of the various sectors shows that the sanitary-paper-products industry (column V) is the least labor intensive, spending only $0.0886 on employment, while pulpwood production (column B), the most labor-intensive sector, spends $0.4041 on employment.

Table 3 shows the direct and indirect effects on the southern forest economy of one exogenous dollar added to any of the processing sectors. Again, values are read only down the columns. For example, if the demand for envelopes (column T) increases $1, there are associated demands of $0.0011 for hardwood stumpage, $0.0099 for softwood stumpage, $0.0012 for logging contractors, $0.0506 for pulpwood producers, $0.0012 for hardwood sawmills, $0.0084 for softwood sawmills, and $0.3366 for paper- and pulpmills. Thus, the overall total from direct and indirect effects is $1.4090 within the forest economy. The in-

Table 4.—*Cash flow in the South Atlantic forest products economy, 1963 (in millions of dollars)*

Selling sector		Forest											
		Logging contractors	Pulpwood producers	Sawmills and planing mills	Veneer and plywood plants	Millwork plants	Prefabricated wood products	Nailed wooden boxes	Other wooden containers	Wood preserving	Other wood products	Nonupholstered wood furniture	
		A	B	C	D	E	F	G	H	I	J	K	
Hardwood stumpage	(1)	17.9	3.2	25.5	2.0								
Softwood stumpage	(2)	28.7	52.5	40.9	.1								
Logging contractors	(3)			77.8	26.2	0.8	0.5	1.0	8.8	17.6			
Pulpwood producers	(4)										5.1		
Sawmills and planing, hardwood	(5)			41.7	4.1	6.6	.9	5.9	3.1	4.8	8.0	101.2	1
Sawmills and planing, softwood	(6)			50.9		22.5	10.9	2.5	1.4	5.8	2.7	2.6	
Veneer and plywood, hardwood	(7)				38.3	13.7			3.1			59.6	
Veneer and plywood, softwood	(8)				.6	2.0	2.0	.2				1.6	
Millwork plants	(9)												
Prefabricated wood products	(10)												
Nailed wooden boxes	(11)												
Other wooden containers	(12)												
Wood preserving	(13)												
Other wood products	(14)											8.6	
Nonupholstered wood furniture	(15)												
Upholstered wood furniture	(16)											1.4	1
Public building furniture	(17)												
Wood partitions and fixtures	(18)												
Paper and pulpmills, except building paper	(19)												
Paperboard mills	(20)												
Envelopes	(21)												
Bags, except textile	(22)												
Converted paper products	(23)												
Folding paperboard boxes	(24)												
Set-up paperboard boxes	(25)												
Corrugated shipping containers	(26)												
Sanitary food containers	(27)												
Fiber cans, tubes, and drums	(28)												
Employment	(29)	34.9	103.4	138.5	40.5	30.4	11.2	7.4	19.4	13.2	18.0	195.9	7
Capital expenditures	(30)	14.0	20.8	29.8	4.5	1.9	1.4	.6	.9	1.9	2.6	30.2	1
Other inputs	(31)	37.2	92.3	157.5	38.0	54.4	27.5	7.0	22.0	26.1	30.3	295.5	16
Total	(32)	132.7	272.2	562.6	154.3	132.3	54.4	24.6	58.7	69.4	66.7	696.6	2

Nonupholstered wood furniture	Upholstered wood furniture	Wood office furniture	Public building furniture	Wood partitions and fixtures	Paper- and pulpmills, except building paper	Paperboard mills	Building paper and board mills	Paper coating and glazing	Envelopes	Bags, except textile	Sanitary paper products	Converted paper products	Folding paperboard boxes	Set-up paperboard boxes	Corrugated shipping containers	Sanitary food containers	Fiber cans, tubes, and drums
K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB
0.0227	0.0078	0.0141	0.0134	0.0094	0.0034	0.0039	0.0011	0.0009	0.0011	0.0018	0.0014	0.0009	0.0018	0.0014	0.0023	0.0016	0.0008
.0108	.0027	.0055	.0078	.0099	.0303	.0367	.0093	.0087	.0099	.0163	.0127	.0078	.0165	.0130	.0219	.0147	.0074
.0434	.0102	.0234	.0262	.0307	.0037	.0038	.0013	.0010	.0012	.0020	.0015	.0009	.0017	.0014	.0023	.0015	.0008
.0006		.0023	.0030	.0015	.1553	.1917	.0473	.0417	.0506	.0834	.0652	.0399	.0862	.0676	.1144	.0767	.0384
.1919	.0789	.1278	.1131	.0498	.0038	.0029	.0022	.0009	.0012	.0020	.0016	.0009	.0013	.0011	.0018	.0012	.0006
.0091	.0033	.0005	.0114	.0196	.0257	.0278	.0083	.0070	.0084	.0138	.0108	.0065	.0126	.0099	.0166	.0111	.0056
.1077		.0450	.0568	.0983													
.0029			.0077	.0338													
.0132		.0038	.0258	.0300													
1.0000																	
.0021	1.0550																
		1.0000															
			1.0000														
				1.0000													
		.0002	.0002		1.0336	.0201	.0046	.1821	.3366	.5541	.4342	.2346	.0277	.0555	.0126	.0138	.0209
		.0112	.0094	.0009		1.0000		.0920		.0009		.0248	.4345	.3137	.5960	.3955	.1870
							1.0000										
								1.0000									
									1.0000								
										1.0000							
											1.0000						
												1.0000					
													1.0000				
														1.0000			
		.0189	.0157	.0016											1.0000		
																1.0000	
																	1.0000
1.4044	1.1579	1.2527	1.2905	1.2855	1.2558	1.2869	1.0741	1.3373	1.4090	1.6743	1.5274	1.3163	1.5823	1.4636	1.7679	1.5161	1.2615

Table 3.—*Total direct and indirect production requirements per dollar of final demand, southern forest products economy, 1963*

		Logging contractors	Pulpwood producers	Sawmills and planing, hardwood	Sawmills and planing, softwood	Veneer and plywood, hardwood	Veneer and plywood, softwood	Millwork plants	Prefabricated wood products	Nailed wooden boxes	Other wooden containers	Wood preserving	Other wood products
		A	B	C1	C2	D1	D2	E	F	G	H	I	J
Hardwood stumpage	(1)	0.1354	0.0165	0.1208	0.0192	0.0491	0.0241	0.0148	0.0070	0.0344	0.0275	0.0443	0.0154
Softwood stumpage	(2)	.2164	.1666	.0333	.1920	.0487	.0463	.0414	.0381	.0323	.0331	.0721	.0201
Logging contractors	(3)	1.0000		.1536	.1421	.2250	.1783	.0604	.0419	.0816	.1344	.2737	.0240
Pulpwood producers	(4)		1.0000										.0451
Sawmills and planing, hardwood	(5)			1.2369		.0347		.0655	.0160	.2892	.1015	.0899	.1414
Sawmills and planing, softwood	(6)				1.1424			.2001	.2040	.1032	.0283	.0914	.0520
Veneer and plywood, hardwood	(7)					1.3238		.1139			.0909		
Veneer and plywood, softwood	(8)						1.0698	.0153	.0340	.0084			
Millwork plants	(9)							1.0000					
Prefabricated wood products	(10)								1.0000				
Nailed wooden boxes	(11)									1.0000			
Other wooden containers	(12)										1.0000		
Wood preserving	(13)											1.0000	
Other wood products	(14)												1.0000
Nonupholstered wood furniture	(15)												
Upholstered wood furniture	(16)												
Wood office furniture	(17)												
Public building furniture	(18)												
Wood partitions and fixtures	(19)												
Paper- and pulpmills, except building paper	(20)												
Paperboard mills	(21)												
Building paper and board mills	(22)												
Paper coating and glazing	(23)												
Envelopes	(24)												
Bags, except textile	(25)												
Sanitary paper products	(26)												
Converted paper products	(27)												
Folding paperboard boxes	(28)												
Set-up paperboard boxes	(29)												
Corrugated shipping containers	(30)												
Sanitary food containers	(31)												
Fiber cans, tubes, and drums	(32)												
Total	(33)	1.3518	1.1831	1.5446	1.4957	1.6813	1.3185	1.5114	1.3410	1.5491	1.4157	1.5714	1.2980

Some multiplier for the entire economy would, of course, be much larger.

While some forest industries have a large influence on demand, others have little. The highest total direct and indirect value found in table 3 is for corrugated shipping containers ($1.7679); the lowest is for building paper ($1.0741). Forest industries also vary in the number of sectors they affect. For example, public-building furniture influences the demand in 12 wood-processing sectors, while the sector for hardwood sawmills and planing mills only influences four categories.

Tables 4, 5, and 6 are similar to table 1 but show the cash flows for the three subregions of the South (fig. 2). Cash flows in the South Atlantic region (Maryland, Delaware, Virginia, West Virginia, North Carolina, South Carolina, Georgia, and Florida) are in table 4. Those in the East South Central (Kentucky, Tennessee, Alabama, and Mississippi) are in table 5, and those in the West South Central (Arkansas, Louisiana, Oklahoma, and Texas) are in table 6. While analysis by State would be advantageous for some purposes, disclosure of production of individual firms would result.

Purchasing sector																		
industries													Final demand					
													Manufacturing and transportation		Construction and maintenance		Final consumer		
Upholstered wood furniture	Public building furniture	Wood partitions and fixtures	Paper- and pulpmills, except building paper	Paperboard mills	Envelopes	Bags, except textile	Converted paper products	Folding paperboard boxes	Set-up paperboard boxes	Corrugated shipping containers	Sanitary food containers	Fiber cans, tubes, and drums	South Atlantic	Other regions	South Atlantic	Other regions	South Atlantic	Other regions	Total
L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE
																			48.6
																			122.2
																			132.7
			85.3	179.4									2.4						272.2
5.3	3.4	1.6	1.7	2.6									1.2	5.6	27.4	5.1			240.3
.7	.2	.8	11.8	20.0									12.2	2.2	148.0	27.2			322.4
	1.3	3.0											17.3	10.1					146.4
	.1	1.4																	7.5
															111.8	20.5			132.3
															48.0	6.4			54.4
													17.1	7.5					24.6
													40.9	17.8					58.7
													5.2	2.3	43.1	18.8			69.4
	.2	1.1											19.4	7.6	10.2	4.4	10.6	4.6	66.5
3.1													30.6	32.1	48.3	50.6	261.1	273.9	696.6
													.9				127.7	134.0	277.3
																	8.5	16.7	25.2
																	14.0	18.6	32.6
			12.2	17.3	10.3	117.3	9.3	2.8	1.0	.2	.7	.8	231.5	156.3					559.7
						.1	.5	53.5	8.2	151.5	48.4	10.1	10.2	605.8					888.3
																	24.0	7.6	31.6
													163.1	63.4					226.5
													3.6	3.8			13.4	14.5	35.5
													87.2	37.0					124.2
													19.0	8.2					27.2
	.3	.1											173.5	73.4					247.4
													82.6	35.0			7.8	3.3	128.7
													37.7	10.3					48.0
6.5	8.6	11.9	116.6	142.5	8.5	44.5	7.7	32.4	8.4	48.4	22.9	15.7							1,157.6
1.3	.4	.9	30.5	88.5	.9	6.1	.4	3.9	.9	7.6	9.2	2.5							271.1
0.2	10.7	11.8	301.6	438.0	11.9	58.5	17.4	31.6	8.7	39.6	47.5	18.9							1,944.3
7.1	25.2	32.6	559.7	888.3	31.6	226.5	35.3	124.2	27.2	247.3	128.7	48.0	955.6	1,078.4	436.8	133.0	467.1	473.2	8,420.0

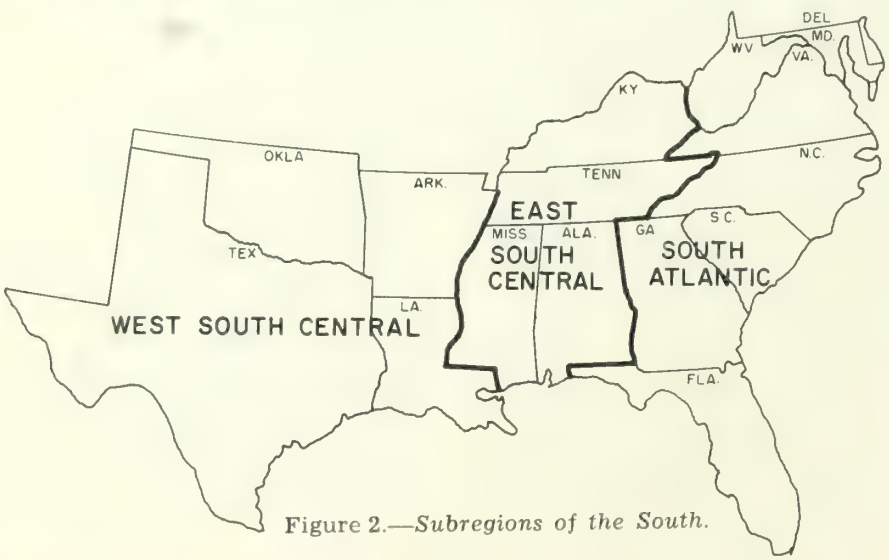

Figure 2.—*Subregions of the South.*

Table 6.—*Cash flow in the West South Central forest products economy, 1963 (in millions of dollars)*

Selling sector		Logging contractors A	Pulpwood producers B	Sawmills and planing mills C	Veneer and plywood plants D	Millwork plants E	Prefabricated wood products F	Nailed wooden boxes G	Other wooden containers H	Wood preserving I	Other wood products J	Nonupholstered wood furniture K
Hardwood stumpage	(1)	4.9	1.4	14.5	0.1							
Softwood stumpage	(2)	11.4	10.8	33.8								
Logging contractors	(3)			38.6	1.7	0.6	0.2	0.3	0.9	11.4		
Pulpwood producers	(4)										1.8	
Sawmills and planing, hardwood	(5)			32.3	.1	4.0	.4	2.6	1.8	1.4	5.4	16.6
Sawmills and planing, softwood	(6)			7.6		22.3	3.8	.9	.4	3.5	5.4	2.4
Veneer and plywood,hardwood	(7)				3.2	8.3			1.6			6.4
Veneer and plywood, softwood	(8)					1.6	.8	.1				.7
Millwork plants	(9)											
Prefabricated wood products	(10)											
Nailed wooden boxes	(11)											
Other wooden containers	(12)											
Wood preserving	(13)											
Other wood products	(14)											1.1
Nonupholstered wood furniture	(15)											
Upholstered wood furniture	(16)											.2
Public building furniture	(17)											
Wood partitions and fixtures	(18)											
Paper- and pulpmills, except building paper	(19)											
Paperboard mills	(20)											
Envelopes	(21)											
Bags, except textile	(22)											
Converted paper products	(23)											
Folding paperboard boxes	(24)											
Corrugated shipping containers	(25)											
Sanitary food containers	(26)											
Fiber cans, tubes, and drums	(27)											
Employment	(28)	11.8	36.1	102.9	6.8	24.4	4.8	3.5	5.0	7.7	11.3	26.4
Capital expenditures	(29)	4.8	7.1	16.4	3.3	2.3	.4	.2	.3	1.1	1.3	3.4
Other inputs	(30)	20.8	23.6	129.3	11.0	45.6	12.4	3.5	6.9	19.7	16.7	39.1
Total	(31)	53.7	79.0	375.4	26.2	109.1	22.8	11.1	16.9	44.8	41.9	96.3

Purchasing sector											Final demand						
											Manufacturing and transportation		Construction and maintenance		Final consumer		
Wood partitions and fixtures	Paper- and pulpmills, except building paper	Paperboard mills	Envelopes	Bags, except textile	Converted paper products	Folding paperboard boxes	Set-up paperboard boxes	Corrugated shipping containers	Sanitary food containers	Fiber cans, tubes, and drums	East South Central	Other regions	East South Central	Other regions	East South Central	Other regions	Total
N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE
																	30.6
																	47.0
																	72.8
	65.4	26.8									1.3						96.5
0.2	1.1	.1									16.9	67.4	22.1	33.8			261.6
.1	4.9	1.7									2.8	4.3	36.4	55.5			149.7
.4											2.2	15.8					48.4
.2																	2.0
													20.4	31.1			51.5
													20.8	2.8			23.6
											7.8	7.4					15.2
											14.9	14.3					29.2
											2.0	1.9	16.9	16.3			37.1
.2											25.2	24.2	14.5	14.0	15.1	14.6	110.9
											2.8	12.4	4.5	19.5	24.2	105.7	169.1
											1.0				22.0	96.1	128.5
															1.6	6.8	8.4
															1.9	8.5	10.4
	19.2	2.3	2.3	51.9	6.3	0.4	0.7		0.1	0.2	25.8	297.5					406.7
					1.6	7.2	3.0	45.6	8.6	1.0		53.7					120.7
															4.1	2.3	6.4
											29.7	60.5					90.2
											2.8	2.9			10.5	11.1	27.3
											8.9	6.4					15.3
											4.9	3.6					8.5
											47.5	34.4					82.0
											10.5	7.6			1.0	.7	19.8
											7.3	4.8					12.1
2.9	34.8	20.2	1.7	21.6	5.4	3.3	2.4	17.3	3.4	2.4							501.9
.2	25.6	4.1	.1	1.5	.4	.4	.3	1.6	.9	.5							111.1
6.2	205.7	65.5	2.3	15.2	13.6	3.5	2.1	17.5	6.8	8.0							777.6
10.4	406.7	120.7	6.4	90.2	27.3	15.3	8.5	82.0	19.8	12.1	214.3	619.1	135.6	173.0	80.4	245.8	3,472.1

Table 5.—*Cash flow in the East South Central forest products economy, 1963 (in millions of dollars)*

Selling sector		Forest industrie												
		Logging contractors	Pulpwood producers	Sawmills and planing mills	Veneer and plywood plants	Millwork plants	Prefabricated wood products	Nailed wooden boxes	Other wooden containers	Wood preserving	Other wood products	Nonupholstered wood furniture	Upholstered wood furniture	Public building furniture
		A	B	C	D	E	F	G	H	I	J	K	L	M
Hardwood stumpage	(1)	12.3	2.8	15.0	0.5									
Softwood stumpage	(2)	16.0	11.3	19.7										
Logging contractors	(3)			51.3	10.6	0.3	0.2	0.3	1.1	9.0				
Pulpwood producers	(4)										3.0			
Sawmills and planing, hardwood	(5)			56.3	.4	4.2		3.4	3.5	3.8	11.7	27.7	8.0	1
Sawmills and planing, softwood	(6)			24.9		6.5	3.3	1.2	.8	2.8	1.9	2.1	.5	
Veneer and plywood, hardwood	(7)				11.6	3.2			2.5			12.3		
Veneer and plywood, softwood	(8)				.3	.6	.4	.1				.3		
Millwork plants	(9)													
Prefabricated wood products	(10)													
Nailed wooden boxes	(11)													
Other wooden containers	(12)													
Wood preserving	(13)													
Other wood products	(14)											3.0		
Nonupholstered wood furniture	(15)													
Upholstered wood furniture	(16)											.3	9.1	
Public building furniture	(17)													
Wood partitions and fixtures	(18)													
Paper- and pulpmills, except building paper	(19)													
Paperboard mills	(20)													
Envelopes	(21)													
Bags, except textile	(22)													
Converted paper products	(23)													
Folding paperboard boxes	(24)													
Set-up paperboard boxes	(25)													
Corrugated shipping containers	(26)													
Sanitary food containers	(27)													
Fiber cans, tubes, and drums	(28)													
Employment	(29)	17.6	41.4	104.5	12.1	12.4	3.8	4.8	7.9	6.0	34.6	54.7	34.0	2
Capital expenditures	(30)	7.4	7.1	38.3	1.0	.6	.3	.3	.2	.6	8.0	7.5	4.0	
Other inputs	(31)	19.5	33.9	101.3	13.9	23.7	15.6	5.1	13.2	14.9	51.7	61.2	72.9	4
Total	(32)	72.8	96.5	411.3	50.4	51.5	23.6	15.2	29.2	37.1	110.9	169.1	128.5	8

Purchasing sector																		
industries												Final demand						
Upholstered wood furniture	Public building furniture	Wood partitions and fixtures	Paper- and pulpmills, except building paper	Paperboard mills	Envelopes	Bags, except textile	Converted paper products	Folding paperboard boxes	Corrugated shipping containers	Sanitary food containers	Fiber cans, tubes, and drums	Manufacturing and transportation		Construction and maintenance		Final consumer		Total
												East South Central	Other regions	East South Central	Other regions	East South Central	Other regions	
L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD
																		20.9
																		56.0
																		53.7
			32.0	43.7								1.5						79.0
5.1	1.7	0.4	.8	.3								24.7	52.1	18.8	10.0			178.5
.1	.4	.1	9.8	9.3								6.5	3.5	78.8	42.1			196.9
	1.3	1.3											.2					22.3
	.3	.4																3.9
														71.1	38.0			109.1
														20.1	2.7			22.8
												7.2	3.9					11.1
												10.9	6.0					16.9
												3.1	1.6	26.1	14.0			44.8
	1.5	.6										11.7	6.1	6.6	3.6	6.9	3.8	41.9
												3.9	4.8	6.1	7.6	33.1	40.8	96.3
2.3												.9				28.7	32.0	64.1
																10.8	25.5	36.3
																8.1	12.2	20.3
			8.1	5.6	4.3	67.9	6.3	0.1	0.1	0.3	0.2	32.0	124.6					249.5
						.3	.3	17.3	74.3	19.3	2.4	2.4	172.3					288.6
																8.9	5.0	13.9
												41.4	84.2					125.6
												3.5	3.6			13.2	13.8	34.1
												23.2	16.8					40.0
	.7											72.7	52.7					126.1
												25.8	18.6					44.4
												6.7	5.4					12.1
7.9	10.0	6.8	57.2	52.8	4.1	24.1	6.4	9.1	24.5	5.8	1.8							461.2
2.0	.9	.3	28.6	16.4	1.0	2.7	.8	.8	3.3	1.5	.6							99.5
6.7	19.5	10.4	113.0	160.5	4.5	30.6	20.3	12.7	23.9	17.5	7.1							785.3
4.1	36.3	20.3	249.5	288.6	13.9	125.6	34.1	40.0	126.1	44.4	12.1	278.1	556.4	227.6	118.0	109.7	133.1	3,351.5

SOLID WOOD INDUSTRIES

The wood products industries (table 1, columns C-J) produced $2,500.4 million worth of materials from stumpage costing $243.3 million. In turn, southern furniture manufacturers relying primarily on these materials (table 1, columns K-O) manufactured goods worth $1,591.4 million. Collectively, the wood products and furniture industries contributed $1,085.7 million in wages to the southern economy and invested $180.1 million.

Lumber and Veneer

Sawmills and planing mills (table 1, column C) led all forest-related sectors in the value of shipments. The South's 7,000 mills marketed $1,349.3 million worth of material—32 percent of the Nation's total. Sawmills and planing mills also led the other sectors in wages paid. They paid 121,083 employees $345.9 million.

Wood inputs for sawmills and planing mills totaled $535.8 million or $0.3935 per dollar of output, compared to the national average of $0.4027. Mills purchased $55.0 million worth of hardwood stumpage and $94.4 million worth of softwood stumpage. They also paid logging contractors $167.7 million for delivering logs to the mills and harvesting stumpage owned by the mills. The remainder of the wood cost, $213.7 million, was for the purchase of lumber that was resawn or surfaced. Over 4 billion board feet or one-third of the lumber produced in the South was further processed by other southern mills.

Hardwood lumber and chips worth $267.8 million were sold to southern forest-related industries. The major customers were manufacturers of nonupholstered wood furniture. Softwood lumber and chips worth $166.9 million was sold to southern forest industries. In addition, $387.2 million worth of softwood lumber was sold to the construction industry.

More workers per unit of output were employed in southern sawmills than in those of other regions. Although the South accounted for one-third of the production and value added in the United States, it employed half the workers (table 7). Southern mills averaged $11,144 output per employee, compared to the national norm of $14,828. Differential regional wage rates, however, give the South a competitive advantage. The wage bill per dollar of output for southern mills is $0.2564 compared to a national average of $0.2604. The data suggest, however, that the South is more vulnerable to rising wage rates than other major forest regions.

A change of $1 in demand for lumber products would elicit a $0.5446 response in the hardwood sector and a $0.4957 in the softwood sector. Over half of the impact would occur in the stumpage and logging sectors.

Table 7.—*The United States and southern wood products industries, by primary product class, 1963* [1]

Primary product class	United States				South			
	Establishments		Employees	Value added by manufacture	Establishments		Employees	Value added by manufacture
	Total	With 20+ employees			Total	With 20+ employees		
	Number			*M dollars*	*Number*			*M dollars*
Sawmills and planing mills	13,372	2,575	242,657	1,572,518	7,187	1,397	121,083	503,304
Veneer and plywood plants	641	503	66,155	559,211	255	204	17,288	95,899
Millwork plants	3,770	748	65,283	524,041	1,011	202	17,100	113,555
Prefabricated wood products	559	203	15,806	156,593	162	58	4,866	38,183
Nailed wooden boxes	663	183	14,483	85,046	139	53	5,007	24,834
Other wooden containers	216	114	13,846	71,692	100	70	10,607	52,990
Wood preserving	388	157	11,178	93,265	206	88	7,270	56,006
Other wood products	2.896	702	57,981	420,283	617	178	16,699	119,156
Total	22,455	5,185	487,389	3,432,649	9,677	2,250	199,920	1,003,927

[1] Source *(13)*.

Regionally, the South Atlantic area led in the production of sawmill and planing mill products. South Atlantic mills accounted for 42 percent of the value of shipments; East South Central, 28 percent; and West South Central, 30 percent. South Atlantic mills ranked first in softwood production, while East South Central mills led in hardwood production.

Other major primary products are veneer and plywood. Plants throughout the South produced $230.9 million worth of veneer and plywood or 16 percent of national shipments. Southern production was mainly hardwood. The South Atlantic area produced 67 percent of the southern output (table 4); East South Central, 22 percent (table 5); and West South Central, 11 percent (table 6).

Wood costs for veneer and plywood plants totaled $99.8 million or $0.4300 per dollar of output. Plants purchased $2.7 million of stumpage while they paid logging contractors $38.5 million. Thus, veneer and plywood plants tend to rely on logging contractors more for their timber supply than do sawmills. Plants also purchased $4.6 million worth of lumber from sawmills. This material is used as core stock in products which are sold mainly to furniture manufacturers. The remainder of the wood cost, $54.0 million, was for veneer utilized by plywood establishments. Plywood plants purchased 1,474 million square feet (surface measure) of hardwood veneer and 5 million square feet (1 inch base) of softwood veneer.

The major structural difference between the sawmill sector and the veneer and plywood sector is the size of establishment. Four-fifths of the sawmills had less than 20 employees, while only one-fifth of the veneer and plywood plants had less than 20 employees (table 7). Southern veneer and plywood plants were similar to sawmills in that they employed a larger number of workers per unit of output than plants elsewhere in the Nation. Southern plants employed 26 percent of the workers but accounted for only 16 percent of the sales volume.

Wood Products

The southern wood products industries are an important market for lumber and veneer. Secondary forest industries, excluding furniture plants, produced $920.2 million of output from $273.2 million of wood inputs (table 1, columns E-J). This output is 21 percent of the national total from such firms. The leading wood product sector is millwork plants.

Of the various wood inputs, lumber was most important. Wood products firms purchased $98.6 million of softwood lumber and $71.5 million of hardwood. Millwork plants led in the purchase of softwood lumber, while manufacturers of other wood products led in the purchase of hardwood. Forest products firms also purchased $62.9 million worth of logs and chips and $40.2 million of plywood and veneer.

Wood products industries employed 61,549 individuals in southern communities and payed $225.8 million in wages. As with the sawmill and veneer industries, southern wood products industries generally employed more individuals per unit of output than similar industries elsewhere in the Nation. But because of the differential in regional wage rates, the wage bill per dollar of output was less in the South than in other areas.

All primary wood-input sectors would be affected by a change in demand for wood products. However, the sector most influenced by a change in demand is sawmills and planing mills. For example, if the demand for prefabricated wood products increases $1, there are indirect-demand increases of $0.0451 for stumpage, $0.0419 for logging contractors, $0.2200 for sawmills, and $0.0340 for veneer and plywood plants. Thus, the overall total from direct and indirect effects is $1.3410.

Among regions of the South, the South Atlantic area led in production of wood products. This region accounted for 44 percent of the output; East South Central, 29 percent; and West South Central, 27 percent.

Furniture

The area's furniture industry is another major market for southern lumber and veneer. In 1963, southern firms accounted for 43 percent of the value added by wood-furniture manufacturers in the Nation, while providing 121,741 employees $454.6 million in wages (table 8). Southern furniture firms (table 1, columns K-O) purchased wood materials worth $303.4 million. Nonupholstered furniture firms were the leaders, purchasing 82 percent of the

wood materials. Other purchasers, in order of importance, were manufacturers of upholstered wood furniture, wood partitions, public-building furniture, and wood office furniture.

Lumber was the leading wood material purchased, as it has been since the early history of furniture manufacturing. Because of lumber's widespread availability, workability, strength, and beauty, southern furniture firms purchased more than a billion board feet of it at a cost of $192.7 million. Hardwood species accounted for $182.7 million, and softwood species $10.0 million. Key lumber species included yellow-poplar, gum, maple, and oak *(1)*.

Plywood is another popular material because of its outstanding strength-weight ratio, dimensional stability, and bonding properties. In addition, a variety of grain patterns can be achieved in veneer. Because of these qualities, southern furniture firms purchased $86.9 million of hardwood veneer and plywood, and $5.4 million of softwood plywood. Veneer accounted for 55 percent of the hardwood expenditure.

Composition board accounted for the remainder of the wood expenditures, $16.5 million; 63 percent was for particleboard, and 37 percent for hardboard.

The South Atlantic area is the center of the southern furniture-wood market (table 4). South Atlantic furniture manufacturers purchased hardwood lumber worth $121.5 million; softwood lumber, $4.3 million; hardwood plywood and veneer, $63.9 million; softwood plywood, $13.1 million; and composition board, $9.9 million; for an overall total of $202.7 million. East South Central firms purchased $56.6 million worth of wood materials (table 5), and the West South Central purchased $40.4 million (table 6).

PAPER AND ALLIED INDUSTRIES

Pulp, paper, and board mills (table 1, columns P-R) made $2,625.1 million worth of products from $437.8 million of pulpwood (row 4) and $65.1 million of chips (rows 5 and 6). Primarily from these outputs, southern paper and paperboard converters produced goods worth $1,773.4 million. Paper and allied industries combined paid out $849.7 million in wages and invested $250.9 million.

Paperboard mills led paper-related sectors in value of shipments. In 1963 the South's 66 paperboard establishments marketed $1,276.6 million worth of output, 56 percent of national shipments. The major types of paperboard manufactured were container board ($708.2 million) and special food board ($238.1 million); southern mills accounted for 64 percent and 74 percent of national shipments of these two products.

Pulpwood inputs for paperboard mills totaled $283.9 million or $0.2188 per dollar of output. More than half the pulpwood produced in the South went to paperboard mills, which spent $249.9 million for 13.0 million cords of round-

Table 8.—*The United States and southern furniture industry, by primary product class, 1963* [1]

Primary product class	United States				South			
	Establishments		Employees	Value added by manufacture	Establishments		Employees	Value added by manufacture
	Total	With 20+ employees			Total	With 20+ employees		
	Number			*M dollars*	*Number*			*M dollars*
Nonupholstered wood furniture	3,063	992	140,982	993,200	832	349	75,248	508,200
Upholstered wood furniture	1,785	713	67,850	506,727	591	305	34,971	233,364
Wood office furniture	138	58	6,516	57,018	29	16	1,740	14,573
Public building furniture	429	164	16,949	141,756	126	56	5,522	32,614
Wood partitions and fixtures	1,594	347	24,343	219,194	322	62	4,260	33,546
Total	7,009	2,274	256,640	1,917,895	1,900	788	121,741	822,297

[1] Source *(13)*.

wood, of which 82 percent was southern pine. Paperboard mills also purchased 1.9 million cords of chips for $34.0 million. Pine roundwood prices varied from a high of $21.08 per cord in the South Atlantic region to $18.86 in the East South Central and $17.07 in the West South Central. A similar trend was present in chip prices. Thus, there is a gradual east to west price differential underlying pulpwood costs.

The rest of the outlays for fiber were for woodpulp. Paperboard mills purchased 168,000 short tons of pulp worth $6.6 million from affiliated or associated mills and 199,000 short tons of pulp worth $18.6 million on the open market.

While the South's paperboard mills are primarily dependent on virgin pulp, paperboard mills in the North operate largely on wastepaper. Nationally, paperboard mills purchased 17.6 million cords of pulpwood and 7.5 million short tons of wastepaper. Of these totals, southern mills purchased 14.8 million cords of pulpwood and 1.1 million short tons of wastepaper. Thus, the South took 84 percent of the Nation's paperboard pulpwood but only 15 percent of the wastepaper.

Paperboard is sold largely to converters located in regions outside the South. Hence, proximity to major industrial centers is a key factor in location of conversion plants. However, the South's expanding industries are encouraging more paper conversion within the region. Southern establishments purchased $480.1 million worth of paperboard. The major customers were manufacturers of corrugated shipping containers, $271.4 million; folding paperboard boxes, $78.0 million; and sanitary food containers, $76.3 million.

Unlike sawmills, southern paperboard mills employ less workers per unit of output than the national norm. Although the South accounted for 56 percent of production and value added, it only employed half of the workers (table 9). Thus, southern mills averaged $40,373 output per employee, while the national norm was $36,531.

Regionally, the South Atlantic led in production of paperboard products. South Atlantic

Table 9.—*The United States and southern paper and allied products, by primary product class, 1963* [1]

Primary product class	United States				South			
	Establishments		Employees	Value added by manufacture	Establishments		Employees	Value added by manufacture
	Total	With 20+ employees			Total	With 20+ employees		
	---- *Number* ----			*M dollars*	---- *Number* ----			*M dollars*
Papermills,[2] except building paper	370	353	144,971	2,153,007	49	47	37,982	634,405
Paperboard mills	271	259	63,398	1,186,224	66	62	32,140	683,054
Building paper & board mills	83	77	11,874	153,103	27	26	4,869	65,892
Paper coating & glazing	387	181	31,983	457,367	39	23	3,159	34,682
Envelopes	230	173	20,728	188,963	43	33	2,938	26,569
Bags, except textile	586	297	42,343	369,685	131	89	18,409	131,306
Sanitary paper products	119	77	19,108	369,711	8	4	1,429	40,797
Converted paper products	610	239	29,514	302,546	72	31	4,430	48,441
Folding paperboard boxes	636	418	51,291	476,866	101	73	9,026	73,987
Set-up paperboard boxes	503	317	20,459	131,688	86	59	3,234	18,990
Corrugated shipping containers	923	651	83,229	804,012	177	129	16,762	154,688
Sanitary food containers	186	144	32,879	402,211	45	36	6,321	87,284
Fiber cans, tubes & drums	246	137	13,188	126,196	59	35	3,990	35,676
Total	5,150	3,323	564,965	7,121,579	903	647	144,689	2,035,771

[1] Source *(13)*.
[2] Includes independent pulpmills.

mills accounted for 69 percent of the value of shipments (table 4); East South Central, 9 percent (table 5); and West South Central, 22 percent (table 6).

Paper- and pulpmills form another important sector of the forest economy. They produced $1,215.9 million worth of materials in 1963. Southern papermills produced $907.3 million, accounting for 24 percent of the national output. All major types of paper were produced, including over 50 percent of the national production of coarse paper (wrapping and shipping sack) and newsprint. Southern pulpmills produced $308.6 million of pulp—51 percent of the Nation's output.

Pulpwood inputs for the paper and pulp industry totaled $212.8 million or $0.1751 per dollar of output. Mills spent $182.7 million for 9.4 million cords of roundwood, 78 percent southern pine. They also purchased $26.5 million worth of softwood chips and $3.6 million of hardwood chips. As with paperboard mills, there is an east to west decline in wood prices.

The remainder of the wood-fiber costs was for 326,000 short tons of pulp. Papermills paid $20.3 million for pulp from affiliated or associated mills and $19.2 million in the open market.

Paper- and pulpmills contributed $258.6 million in wages to southerners. They employed about the same number of workers per unit of output as the national norm. Southern papermills averaged $29,821 of output per employee compared to the national norm of $29,457.

Regionally, the South Atlantic led in the production of paper and pulp. South Atlantic mills manufactured $559.7 million of output (table 4); East South Central, $406.7 million (table 5); and West South Central, $249.5 million (table 6). Mills producing only pulp are concentrated in the South Atlantic region, where 70 percent of this product is made. South Atlantic papermills manufactured 38 percent of the South's production; East South Central, 35 percent; and West South Central, 27 percent.

The remaining primary processing sector is the building-paper industry. Building-paper mills purchased $6.2 million of pulpwood, of which $5.2 million was for 299,000 cords of pine. From this input, the 27 establishments marketed $111.6 million worth of output. Four-fifths of production was insulating board, and one-fifth was construction paper.

CONVERTED PAPER PRODUCTS

Northern converters are the major buyers of southern paper and paperboard, but the southern market continues to gain in importance. Southern paper and paperboard converters produced $1,773.4 million of output from paper and board inputs totaling $836.5 million (table 1, columns S-BB). This output was 19 percent of the national total. The leading southern sector was corrugated shipping containers, followed closely by bags. These sectors account for one-half of the production from converted paper industries.

Of the two major inputs, paperboard was most important. Southern converters purchased $467.5 million worth of paperboard and $369.0 million of paper. Thirty-four percent of the paperboard and 42 percent of the paper was purchased from affiliated or associated mills.

Converters employed 70,000 people in southern communities and paid $347.3 million in wages. The South's converting plants employed about the same number of individuals per unit of output as similar industries elsewhere in the Nation.

All primary-wood-input sectors are affected by a change in demand for converted paper products. However, the sector most influenced by a change is pulpwood production. If the demand for corrugated shipping containers changes $1, there are associated demand increases of $0.0023 for hardwood stumpage, $0.0219 for softwood stumpage, $0.0023 for logging contractors, and $0.1144 for pulpwood producers. These responses, coupled with a $0.6270 response in the sawmill, paper, and paperboard sectors, totals $1.7679, the highest for any forest-related sector.

Regionally, the South Atlantic leads in the production of converted paper products. South Atlantic paper-converting establishments purchased $272.3 million worth of paperboard and $142.4 million worth of paper (table 4). South Atlantic conversion plants accounted for 57 percent of the output; East South Central, 17 percent (table 5); and West South Central, 26 percent (table 6).

LITERATURE CITED

1. Applefield, M.
   1965. Sources of lumber for furniture plants in North Carolina, 1963. USDA Forest Serv. Southeast. Forest Exp. Sta., 5 pp.

2. Bourque, P. J., Chambers, E. J., Chiu, J. S. Y., and others.
   1967. The Washington economy: an input-output study. Grad. Sch. Bus. Admin., Univ. Wash., and Wash. State Dep. Com. and Econ. Develop., Bus. Stud. 3, 37 pp.

3. Bradley, I. E.
   1967. Utah interindustry study: an input-output analysis. Utah Econ. and Bus. Rev. 27(7): 1-12.

4. Bureau of the Budget.
   1957. Standard industrial classification manual. 433 pp. Executive Office of the Pres. Wash., D. C.

5. Carden, J. G. D., and Whittington, F. B., Jr.
   1964. Studies in the economic structure of the State of Mississippi. Vol. 1. Miss. Ind. and Technol. Res. Comm., Jackson, Miss.

6. Gamble, H. B.
   1968. The regional economic role of forest products industries. J. Forest. 66: 462-466.

7. Gamble, H. B., and Raphael, D. L.
   1965. A microregional analysis of Clinton County, Pennsylvania. 80 pp. Penn. Reg. Anal. Group, Penn. State Univ., Univ. Park.

8. Gill, T. G.
   1965. Wood used in manufacturing industries. USDA Statist. Bull. 353, 121 pp.

9. Leontief, W. W.
   1951. Structure of the American economy, 1919-1939; an empirical application of equilibrium analysis. Ed. 2, 264 pp. New York: Oxford Univ. Press.

10. Oser, J.
    1963. The evolution of economic thought. 399 pp. New York: Harcourt, Brace, & World Inc.

11. Thuemmes, R. E., editor.
    1964. Lockwood's directory of paper and allied trades. Ed. 89, 1604 pp. New York: Lockwood Trade J. Co., Inc.

12. USDA Forest Service.
    1965. Timber trends in the United States. USDA Forest Serv. Resource Rep. 17, 235 pp. U. S. Government Printing Office, Wash., D. C.

13. USDC Bureau of the Census.
    1966. Census of manufactures, 1963. Industrial and area statistics. U. S. Dep. Com., 4 vols. Wash., D. C.

14. USDC Bureau of the Census.
    1966. 1963 census of transportation. Commodity transportation survey. U. S. Dep. Com., 3 vols. Wash., D. C.

15. USDL Bureau of Labor Statistics.
    1963. Wholesale prices and price indexes. U. S. Dep. Labor, Wash., D. C.

APPENDIX

DEFINITIONS OF CLASSES

The definitions given below are based mainly on material in the SIC Manual *(4)*.

Logging contractors (SIC 2411): Logging contractors are primarily engaged in cutting timber and in producing rough, round, hewn, or riven primary forest or wood raw materials. Logging and woods operations conducted in combination with sawmills and other converting establishments, and not separately reported, are classified in their respective industry groups. Products manufactured in this class include poles, saw logs, posts, and veneer logs.

Pulpwood producers: Pulpwood producers are primarily engaged in cutting wood to be mechanically ground or chemically digested for subsequent manufacture into paper, fiberboard, or other products. This class was formed to isolate pulpwood harvesting from other logging operations.

Sawmills and planing mills (SIC 2421, 2426, and 2429): Establishments engaged in sawing rough wood materials and in operations that produce surfaced lumber and standard pattern material. Hardwood dimension lumber and flooring establishments, conventionally treated as a separate unit, are also included in this industry. Outputs include lumber, planed and surfaced materials, furniture dimension stock, dimension lumber, flooring, lath products, and gun stocks.

Veneer and plywood plants (SIC 2432): Establishments primarily engaged in producing commercial veneer and commercial plywood. Typical products include decorative panels, plywood, and veneer.

Millwork plants (SIC 2431): Establishments primarily engaged in manufacturing fabricated millwork. Products manufactured include door trim, cabinet wood, storm-window wood, and interior woodwork.

Prefabricated wood products (SIC 2433): Establishments primarily engaged in manufacturing prefabricated wooden buildings, sections, and panels; or in producing laminated or fabricated trusses, arches, and other structural members.

Nailed wooden boxes (SIC 2441): Establishments primarily engaged in manufacturing nailed and lock-cornered wooden boxes made of lumber or plywood. Products manufactured within this class include ammunition boxes, greenhouse flats, nailed packing cases, carrier trays, and cigar boxes.

Other wooden containers (SIC 2442 and 2443): Industries contained within this class manufacture wirebound boxes and crates. Also included are establishments that produce veneer and plywood containers or baskets. Items produced include fruit crates, chicken crates, fruit hampers, wooden pails, and plywood drums.

Wood preserving (SIC 2491): Establishments primarily engaged in treating wood with creosote or other preservatives to prevent decay and to protect against fire and insects. The industry produces treated trestles, crossties, mine props, poles, and posts.

Other wood products (SIC 2499): Establishments primarily engaged in turning and shaping wood, and in manufacturing miscellaneous wood products not elsewhere classified, such as hardboard, pressed particleboard, wood pallets, and skids.

Wood furniture, not upholstered (SIC 2411): Establishments primarily engaged in the manufacture of unupholstered household wood furniture. The industry makes cabinets, desks, dressers, beds, tables, and bookcases.

Wood furniture, upholstered (SIC 2512): Establishments primarily engaged in manufacturing upholstered furniture on wooden frames, or in manufacturing the wooden frames for upholstered furniture. Shops primarily engaged in reupholstering furniture, or in upholstering frames to individual order, are considered nonmanufacturing industries.

Wood office furniture (SIC 2521): Establishments primarily engaged in manufacturing wood office furniture, whether padded, upholstered, or plain. Items produced by this industry include office bookcases, benches, desks, and chairs.

Public building furniture (SIC 2531): This industry includes establishments that produce furniture for schools, theaters, assembly halls, churches, and libraries. Manufacturers of seats for public conveyance systems and seats for

automobiles and aircraft are also included. Typical products are bleachers, railroad seats, and church pews.

Wood partitions and fixtures (SIC 2541): Establishments primarily engaged in manufacturing wood shelving, lockers, office and store fixtures, prefabricated partitions, and related fabricated products. Refrigerator cases or cabinets are not included. Products manufactured by this industry include wooden bar fixtures, show cases, prefabricated partitions, and lockers.

Paper- and pulpmills, except buildings (SIC 2611 and 2621): This industry is composed of establishments that manufacture paper from woodpulp and other fibers. Items produced include woodpulp, fiber pulp, paper bags, facial tissue, text paper, and kraft wrapping paper.

Paperboard mills (SIC 2631): This industry is mainly engaged in the manufacture of paperboard from woodpulp and other fibers. Boxboard, cardboard, leatherboard, and shoeboard are produced by this industry.

Building-paper and board mills (SIC 2661): Establishments primarily engaged in manufacturing building paper and building board from woodpulp and other fibrous material. Products manufactured in this industry include construction paper, insulation board, wood-fiber roofing, and tar paper.

Paper coating and glazing (SIC 2641): Included here are establishments that primarily manufacture coated, glazed, or varnished paper from purchased paper. Typical products include wax paper, waterproof wrapping paper, gummed labels, and litmus paper.

Envelopes (SIC 2642): This industry contains establishments that primarily manufacture envelopes of any description from purchased paper and paperboard.

Bags, except textile (SIC 2643): Establishments primarily engaged in manufacturing bags from purchased paper, cellophane, acetate, polyethylene, pliofilm, foil, and similar sheet or film materials. End products of these establishments include flour bags, freezer bags, shipping sacks, and garment storage bags.

Sanitary paper products (SIC 2647): This industry includes establishments engaged in manufacturing sanitary paper products from purchased paper. Toilet paper, facial tissues, table napkins, and paper diapers are typical products.

Converted paper products (SIC 2649): This industry contains establishments primarily engaged in manufacturing purchased paper products into miscellaneous converted paper or paperboard products not elsewhere classified. Products manufactured include paper excelsior, stationary, notebooks, gift wrapping paper, and crepe paper.

Folding paperboard boxes (SIC 2651): Establishments primarily engaged in manufacturing folding paper boxes from purchased paper.

Set-up paperboard boxes (SIC 2652): Establishments primarily engaged in manufacturing set-up paper boxes from purchased paper. Products include filing boxes and newsboard boxes.

Corrugated shipping containers (SIC 2653): Establishments primarily engaged in manufacturing corrugated and solid fiber boxes and related products from purchased paperboard of fiber stock. Important products of this industry include corrugated and solid fiberboard boxes, pads, partitions, display items, pallets, single-faced products, and corrugated sheets.

Sanitary food containers (SIC 2654): This industry is composed of establishments primarily engaged in manufacturing special food board into food containers such as fluid milk containers, folding paraffined containers, frozen food containers, paper cups, and ice cream cartons.

Fiber cans, tubes, and drums (SIC 2655): Establishments primarily engaged in manufacturing fiber cans, cones, drums, and similar products, with or without metal ends, from purchased material. Typical products are paper bottles, ammunition cans, mailing cases, and fiber wastebaskets.

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Determinants of Southern Pine Pulpwood Prices

Pulpwood is of major importance to the southern forest economy. It ranks first in total output among all southern pine roundwood products and constitutes half of the cubic-foot volume removed from southern forests each year.

This paper analyzes the price determinants of southern pine pulpwood stumpage. It updates studies previous to 1968 and extends coverage from the Midsouth States of Alabama, Arkansas, Louisiana, Mississippi, and Texas to the entire South. In studies from 1955-1960 *(3)* and 1955-1965 *(1)*, forest economists found that most of the price variation could be explained by four factors: (1) local competition for pulpwood, (2) general demand for pulpwood, (3) forest stand conditions, (4) the kind of wood included in the sale, i. e., the proportion of the total volume removed that was made up of sawtimber tops and hardwoods. These studies also showed that the wage rates paid pulpwood cutters affected stumpage price trends.

The Data

As in the two previous studies, the prices analyzed were those paid for pine pulpwood stumpage sold from National forests in the South. National forest sales were studied primarily because records of them are available while records of private sales of pine pulpwood stumpage generally are not.

The price data were taken from the files of the Southern Region (Region 8) of the USDA Forest Service. In addition to price received per standard cord, each record showed the advertised price, the bid price, and the date and location of sale. Competition for the stumpage was measured in terms of the number of bidders. Total volume and acreage in the sale area were also included.

Only data from pine pulpwood sales on southern National forests from 1960-1967 were analyzed. Hence, no mixed pine-hardwood sales were included, unless the hardwood component amounted to less

than 10 percent of the volume. Neither combination pulpwood-sawtimber sales nor negotiated sales were accepted.

No sales from National forests in Virginia, Tennessee, or North Carolina qualified. The distribution of the 725 acceptable sales was:

Region and State	Number of sales
Arkansas	160
Louisiana	97
Texas	19
West Gulf	276
Alabama	68
Mississippi	156
East Gulf	224
Florida	148
Georgia	56
South Carolina	21
Southeast	225
Total	725

Means and ranges for selected characteristics of the sales were:

Characteristic	Mean	Range
Volume in standard cords	1,600	20-7,700
Acreage	715	20-3,750
Cord volume per acre	3.3	1-25
Number of buyers	4	1-9

National forest transaction data appear to be particularly suitable for price analysis for several reasons. When sales from only one agency are taken, much of the random variation that could occur due to differences among individual sellers is eliminated. There is uniformity in marking and estimating, in sales procedure, and in record keeping. These sales also reflect prices that acknowledgeable buyers and sellers can agree upon.

For several reasons, prices for National forest stumpage are not necessarily typical of those for all pulpwood sales, private and public. Ordinarily National forest sales are much larger than private sales, hence fewer operators compete for them. Neither buyer nor seller is under compulsion to complete the sale. In addition, a firm reserve price based on an appraisal is advertised with the offer to sell. No prospective buyer bids less than the reserve price, since such offers would be rejected.

Prices paid for National forest stumpage, however, probably do not differ greatly from those paid for private timber. Since pur-

chasers of National forest stumpage have the choice of buying private timber, these alternative sources of supply should prevent overpricing of public timber. On the other hand, because of the reserve price, it seems unlikely that public timber is purchased for much less than private stumpage.

Analysis and Results

The price data were analyzed by multiple regression. The price model that was hypothesized contained 10 independent variables. The model took the form:

$$P = V + A + V/A + V \times V\ A + B + PA + R + M + M^2 + M^3$$

where:

- P = price (dollars per standard cord)
- V = volume sold (standard cords)
- A = acreage of sale area
- V/A = volume per acre
- $V \times V/A$ = interaction of total volume and volume per acre
- B = number of firms buying pulpwood in county
- PA = pulpwood market activity in State (change in pulpwood cut between year prior to sale and 2 years prior to sale, adjusted for acreage of pine type)
- R = region (West Gulf, East Gulf, or Southeast)
- M = month of sale (three-digit serial number assigned to each month from 001 for January 1955)
- M^2 = month of sale squared
- M^3 = month of sale cubed

All except two of the variables were readily determined from the sales records. The number of firms buying pulpwood and the pulpwood market activity were obtained from other sources. County tabulations of the number of firms buying roundwood are prepared for annual reports of southern pulpwood production. An index of pulpwood market activity is calculated for each State on the basis of pulpwood production reports.

Endogenous variables in the price model, those subject to control by the seller, are number of cords sold and acreage of sale area. Two independent variables derived from these two measurements—volume per acre and the interaction of total volume and volume per acre—are also endogenous. The remaining independent variables, which refer to place and time of sale, are exogenous, i. e., external to the sale and beyond control of the seller. Once the location of the timber offered for sale has been established, price determinants are the subregion in which the tract lies, pulpwood market activity in the

State, and number of buyers in the county. Month of sale in its linear, quadratic, and cubic forms is also considered an exogenous variable even though the seller can exert limited control over the exact time at which he puts the timber on the market. If the timber is on a managed forest, the range of time in which to sell is very narrow.

Although external and internal variables are equally important in explaining price behavior, the variables that the seller can control are of primary interest to him if he wants to mark his stands for the highest unit value. When the owner intends to predict the price his particular stand of pulpwood may bring, however, he becomes concerned with all price determinants.

A price estimating equation was developed from the collected data and the price model. Analysis showed that of the 10 factors, seven were statistically significant at the 5 percent level. Stand characteristics retained in the equation were volume, acreage, and interaction of total volume and volume per acre. The market factor, number of firms buying in the county, was also included. In addition, the significant forms of the time variable were found to be month and month cubed.

Orthogonal comparisons indicated that the coefficients for the significant independent variables were practically identical for each region. But the price level in the Southeast differed substantially from that in the Midsouth (West Gulf and East Gulf combined). Within the Midsouth there was no significant difference in the price level between the West Gulf and East Gulf.

The estimating equation for the stumpage price of pine pulpwood in the Southeast is:

$$\hat{Y} = 9.4694 + 0.4058X_1 - 0.0729X_2 - 0.0161X_3 + 0.2255X_4 - 0.0648X_5 + 0.0019\frac{X_6}{1{,}000}$$

where:

$\hat{Y}$ = estimated pine pulpwood stumpage price (dollars per standard cord)
X_1 = volume sold (thousand standard cords)
X_2 = size of sale area (hundred acres)
X_3 = total volume (thousand standard cords) times volume per acre (standard cords)
X_4 = buyers (number)
X_5 = month of sale (serial numbers where January 1955 = 001)
X_6 = month cubed

For the Midsouth, the estimating equation is identical with that for the Southeast, except for the value of the constant. The value of

the constant for the Midsouth is 7.43892, indicating that stumpage prices for pine pulpwood in the Midsouth average about $2 less than prices in the Southeast.

The equation accounts for 56 percent of the price variation, and the standard error of estimate is $1.50. Expressed in terms of the southwide mean price, the equation has a standard error of 31 percent.

The significant form of the time variable was a combination of month and month cubed. Previous studies have shown that from 1955-1953 prices rose to a peak and then began falling. In this study, prices continued to fall from 1960-1963, then began a rise that continued to the end of the period, in 1967 (fig. 1). Prices declined approximately $1.10 during the first part of the period and then rose about $1.75 during the last part.

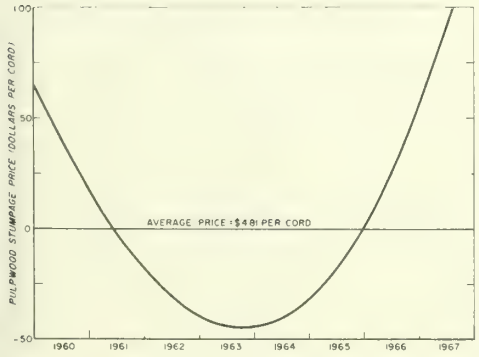

Figure 1.—*Pattern of average pulpwood stumpage price movement, 1960-1967.*

The stumpage price pattern reflects trends both in demand for pine roundwood pulpwood and in general prices. In both the Midsouth and the Southeast, annual average prices for pine roundwood delivered to mills and woodyards followed roughly the same pattern. The price decline appears to have resulted primarly from the rapid substitution of hardwoods and plant residues for pine roundwood between 1960 and 1963. During this period, pulpwood production rose. Pine roundwood output, however, increased only modestly; when expressed as a percent of total pulpwood output it decreased from 70 to 64 percent. Increases in pulpwood production were accounted for mainly by increases in the production of hardwood bolts and the salvage of plant residues. Moreover, a significant proportion of the relatively stable demand for pine bolts was shifted to areas in which competition was low. During this 4-year period, the Bureau of Labor Statistics wholesale price index declined very slightly. From 1964 onward, percentage increases in pulpwood production were matched by equivalent percentage increases in pine roundwood output. At the same time, wholesale prices began rising. As inflationary pressures grew, wholesale prices rose at an increasingly rapid rate each year for the duration of the period.

From year to year and month to month, pulpwood prices fluctuated around the trend line. Average annual prices for the entire period were:

1960	$5.91 per cord	1964	$4.04 per cord
1961	4.66 " "	1965	5.02 " "
1962	5.21 " "	1966	6.29 " "
1963	3.28 " "	1967	5.89 " "

Some month-to-month price variation was seasonal. A 12-month moving average was used to approximate the normal seasonal price pattern (fig. 2). During a typical year, average monthly prices ranged from a low of 88 to a high of 124, on a scale where the monthly average equalled 100. The low point was reached in the spring, and the high point in late summer. Although prices did not follow precisely the same pattern every year, the plotted monthly averages for each year indicated that a seasonal pattern prevailed and that it had not shifted.

Figure 2.—*Average seasonal variation in pine pulpwood stumpage prices, 1960-1967.*

Seasonal weather conditions can have been only partly responsible for this price pattern. In spring, which is normally wet, prices are low, but they are highest in the summer, which is not a particularly dry season. And in the fall, which is driest, prices are low.

Seasonal availability of rural labor is perhaps the principal factor influencing the pattern of prices. In the spring, much rural labor is engaged in planting crops and is not available for cutting pulpwood. By midsummer, however, the labor force is free from farm work. In the fall rural labor is busy harvesting farm crops.

Size of sale is positively related to price (fig. 3). For each thousand-cord increase in sale size, price advances by roughly 38 cents. With each increase in volume the price advance is less when total vol-

ume is high than when it is ow. The declining influence on price of additions to volume is more pronounced on small acreages than on large tracts.

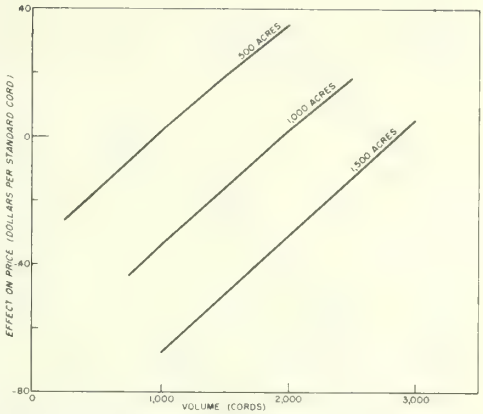

Figure 3.—*Pine pulpwood prices rise with increases in volume of wood sold but decline with increases in acreage of sale area when wood volume is held constant.*

Size of sale is determined jointly by acreage of sale area and density, i. e., cords per acre. Hence, the influence of these stand characteristics or their derivatives on price cannot be determined separately. In the price equation, both volume and area appear as independent linear variables; there is a positive coefficient for volume and a negative one for area. In addition, these two variables also appear with a negative coefficient in the interaction of total volume and volume per acre. The interrelationship between these factors is responsible for the positive, slightly convex curve relating volume to price. The upward slope of the curve is explained in large degree by the economies of scale possible in logging large volumes of timber compared with small ones. At the same time, however, large sales result in less competition, which depresses the price.

There was a negative relation between price and acreage. It cannot be explained entirely by less competition among buyers for large sales. With volume held constant, an increase in acreage would be expected to result in a lower price because average volume per acre would be forced downward. Logging studies typically show that costs ascend (and consequently price declines) when volume cut per acre falls *(2)*.

The number of local pulpwood market outlets also influences price (fig. 4). Each additional firm that buys pulpwood in a county causes an increment of approximately 22 cents in the average price per cord.

The effect on price of competition among buyers was examined for 148 sales in Florida, where stumpage prices are highest and competition for pulpwood greatest in the South. Answers were sought to two questions: To what extent does competition influence stumpage prices? And is the significant competitive factor the actual number of bidders or the proportion of prospective buyers that bids?

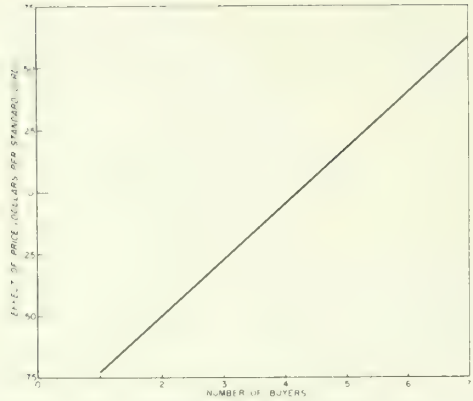

Figure 4.—*Pine pulpwood stumpage prices rise with increases in the number of pulp and paper firms buying pulpwood in the county.*

Analysis of Florida sales showed that the number of bidders exerts a major influence on price paid. When possible price determinants were screened by comparing the simple correlation of each factor with price, a correlation coefficient of 0.425 was obtained for bidders. This value greatly exceeded that obtained for any other factor tested. The simple regression of bidders on price indicated that price increased 53 cents with each additional bidder. Number of bidders explained 18 percent of the price variation, and this factor alone predicted price with an error of $1.75 (24 percent at the mean). Number of bidders divided by the number of buyers in the county was not a significant variable.

Since National forest timber sales involve advertising a minimum acceptable price, there is suspicion that this procedure may confound price analysis. The argument is that since the advertised price constitutes a large proportion of the final price, the judgments of the appraisers who set the advertised price may predominate. At worst, the price analysis may merely confirm the factors taken into account by appraisers rather than revealing the actual price-making factors operative in a free stumpage market. If the appraisers differ sharply from the combined judgments of the buyers, results of the analysis could be erroneous.

The bid premium, which is independent of the advertised price, offers a partial test of the validity of this proposition. It should reflect the functioning of competitive factors in the market. Therefore, the determinants of price identified by the analysis were compared with the determinants of bid premium, even though the size of the dependent variables was not similar. Sales from Florida were also analyzed for this purpose.

The comparison revealed no major differences that would support the hypothesis that the price determinants identified in the analysis were invalid. The time variable was present in both equations, as was the competition variable. On the other hand, pulpwood market activity was a significant factor in the price equation but not in the bid-premium equation. Stand characteristics were repre-

sented in the price equation by volume per acre, while in the bid-premium equation they were represented by the interaction of total volume and volume per acre.

Discussion

The price trend found in this study and earlier studies *(1, 2)* was affected by changes in roundwood requirements of the pulp and paper industry. Demand for pulp and paper has been rising. Expansion of pulping capacity and modification of pulping processes to increase the yield from each cord of wood have also had an effect. Substitution of hardwoods and plant residues for pine roundwood tended to depress prices. The general price inflation, particularly in wage rates, tended to increase prices.

Regional prices were significantly different. In the two previous studies, which were limited to a single region, price dissimilarities among States were explained primarily in terms of number of buyers, although transportation costs accounted for some of the differences. Similarly, competition among buyers apparently causes average prices to be lower in the Midsouth than in the Southeast. The Southeast has both more and larger pulpmills than the Midsouth.

In addition, the number of pulp companies drawing wood from a county greatly affected price. This finding agrees with that for 1955-1965 sales. The effect of each additional buyer was to increase price per cord by 22 cents, which agrees closely with the 20-cent increment determined in the earlier study.

Total volume cut per acre also influenced price. This factor was significant in both previous studies, but its effect appears to have changed. In the 1955-1960 study, price declined as total volume increased. In the 1955-1965 study, price increased 20 cents per cord for each additional thousand cords offered. In the present study, price increased approximately 28 cents per cord with each addition of a thousand cords.

The variation in results among these three studies may reflect changes that have occurred in industry structure and in pulpwood production practices. Rising wage rates, scarcity of rural labor, and other factors have encouraged pulpwood producers to mechanize their operations. As a result, other changes have occurred that could affect stumpage prices. For example, pulpwood producers have had to expand output to finance heavier investments in machinery. Also, the minimum size of sale that they can afford to operate has risen and stand characteristics such as volume per acre have become more crucial. In addition to expanding capital investment, more and more pulpwood producers are adopting harvesting practices such as tree-length logging.

The results of this analysis provide adequate guides to pulpwood stumpage prices in the short run. In tne long run, however, stumpage price relationships are expected to be substantially different. Among the responsible factors will be changes in the ratio of capital to labor, in logging methods, in transportation systems, and in other elements of production. Pulpwood producers will be stimulated to adopt new methods as they compete with other forest products firms for timber and seek to deliver wood to the millyard at the lowest possible cost.

Literature Cited

1. Fasick, C. A., and Sampson, G. R.
   1966. Price behavior of pine pulpwood stumpage from national forests in Mid-South: 1955-1965. Pulpwood Prod. 14(3): 18, 20.
2. Guttenberg, S., and Perry, J. D.
   1957. Pulpwooding with less manpower. USDA Forest Serv. South. Forest Exp. Sta. Occas. Pap. 154, 34 pp.
3. Row, C., and Guttenberg, S.
   1961. Why pulpwood stumpage prices vary. Pulpwood Prod. 9(10): 14, 16.

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Development of a Year's Height Growth In Longleaf Pine Saplings

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Development of a Year's Height Growth In Longleaf Pine Saplings

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Most of a group of longleaf pine (Pinus palustris *Mill.) saplings observed in southern Mississippi appeared to be capable of continuous elongation throughout the growing season in a favorable environment. Heavy competition tended to reduce summer growth more than spring growth.*

On winter terminal buds, all sections between the base and the rounded shoulder of the tip began elongating simultaneously and grew at equal rates until, starting with the basal section, each in turn culminated its growth. Thus, elongation was progressively greater for each section from the base toward the tip. Activity in the tip of the bud was not visible until about 40 days after elongation had started at the base.

In saplings that made five flushes of growth in addition to forming a winter bud, elongation started in the third flush just before it stopped in the first. At least two flushes were always rapidly elongating from mid-April until mid-July.

The number of flushes produced by a tree in one growing season was interpreted to be more of a function of a tree's moisture regime than of the amount of available photosynthate.

This paper describes the complex seasonal growth patterns of longleaf pine saplings. The studies reported were exploratory, but the data, observations, and speculations presented should help in planning detailed studies on individual aspects of height growth in the southern pines.

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Many authors have concluded that, within a species, there is relatively little variation in the pattern of height growth from year to year (e. g., *5*, *11*, and citations therein). This conclusion is sometimes interpreted to mean that the seasonal growth pattern is under strong hereditary control. Kozlowski and Ward *(6)*, however, showed that the amount of seasonal variation in the growth patterns is small among individuals of some species and large among those of others. The amount of hereditary control often depends upon the individual worker's definitions of growth patterns and hereditary control *(4)*. The authors just cited found that although the length of the growing season was relatively stable for *Pinus resinosa* Ait., the rate of growth was highly variable and dependent upon the immediate environment. They concluded that the pattern of growth was related more to the fluctuating environment than to the genetic qualities inherent in the individual tree. Wilcox and Farmer *(12)* demonstrated in their work with rooting that the degree of heritability expressed is dependent, in part, upon the environment. Thus, the patterns of height growth and the factors that influence them are complex for all species.

A year's height growth in a southern pine is usually the result of the elongation of a winter bud and one or more summer buds *(3)*; each elongation is called a flush. Tepper *(9)* described the elongation of multinodal winter buds of pitch and shortleaf pines (*P. rigida* Mill. and *P. echinata* Mill.), and showed how this elongation contributed to total growth. Both Eggler *(3)* and Tepper *(9)* reported tree to tree variation in the number of flushes. Wakeley and Marrero *(10)* indicate there may be as many as six summer shoots contributing to the annual growth of the main terminal. Eggler *(3)* pointed out that when elongation resulted from two or more buds, the buds elongated consecutively rather than intermittently, and Tepper *(9)* reported that elongation of the summer shoot sometimes overlapped the elongation of the spring shoot in shortleaf pine. Thus, the pattern of leader growth of southern pines is considerably more complex than that of most trees native to the Northern United States, where only one flush of growth is ordinarily produced each year.

Seasonal Patterns

Methods

In 1958, 10 longleaf pine saplings growing in a stand on cutover land in the Harrison Experimental Forest near Gulfport, Mississippi, were randomly selected for study. They were approximately 10 years old and 4 feet tall. The saplings grew under various amounts of competition, but they were representative of the stand, which in turn, appeared typical of natural stands of young longleaf pine in the area.

A stainless steel pin was placed at the base of the terminal bud of each of the saplings in February 1958. With the pin as a reference point, bud lengths were measured to the nearest millimeter at weekly intervals throughout the growing season. A pin was also inserted into the base of each new terminal bud as soon as the sterile cataphylls could be recognized. Measurements were made between successive pins as well as to the tip of the bud. Elongations of individual buds were then plotted over time. Six saplings were selected to represent the range of growth curves found among the original 10. These six were remeasured in 1959.

In January 1960, four of the six saplings were released, fertilized, mulched, and thereafter watered during dry periods. All competing trees and brush were cut in a 12-foot radius around a sapling to release it. A 4-inch layer of pine-straw mulch was broadcast over the same area. Two and one-half pounds of fertilizer (5-10-5) per tree were broadcast on top of the mulch on January 5 and again on April 28. One hundred and twenty gallons of water were applied to each of the four saplings on two occasions. The other two saplings remained as untreated controls.

Before release, a competition index was obtained by assigning a factor to each woody plant (mostly other saplings but some gallberries (*Ilex glabra* L.)) within a 12-foot radius around the study tree:

$$\text{Factor} = \frac{\left(\frac{\text{Diameter of competing tree}}{\text{Diameter of study tree}}\right) \times \left(\frac{\text{Height of competing tree}}{\text{Height of study tree}}\right)}{\text{Distance (ft.) of competing tree from study tree}}$$

Diameters of both trees and gallberries were measured 1 foot above ground line.

The individual factors for surrounding vegetation were totaled to determine the competition index of a study tree. The accuracy of this index is not known, but it should give a relative measure of competition for each study sapling.

Pine shoot moths (*Dioryctria amatella* Hulst.) killed the terminal shoots of the fertilized trees in late April 1960. Therefore, the terminals of all six saplings were cut and measurements were discontinued for the remainder of 1960. One of the lateral buds at the base of the original terminal soon took over on all six saplings, and these new terminal buds were sprayed monthly with 0.5 percent benzene hexachloride for moth control during the balance of the growing season.

Weekly measurements were resumed on the saplings early in 1961 and continued throughout the growing season. Two and one-half pounds of 5-10-5 fertilizer were applied to each of the four released trees on January 26 and again on June 8. Trees were not irrigated

in 1961. Buds on all of them were dusted lightly with 10 percent DDT powder once a week, and no insect damage occurred. Yearly height increases were recorded at the end of September in 1962, 1963, and 1964.

Rainfall records were obtained from a weather station at Saucier, Mississippi, which is about 2 miles from the study area. Monthly totals are given in table 1.

Table 1.—*Monthly rainfall (inches) at Harrison Experimental Forest, Saucier, Mississippi*

Month	Year								1946-63 average
	1957	1958	1959	1960	1961	1962	1963	1964	
January	1.34	5.83	4.01	8.74	5.63	6.06	4.79	8.16	4.52
February	1.48	3.26	8.25	6.13	9.52	5.10	5.02	4.41	4.46
March	5.58	9.20	4.54	4.80	10.80	3.49	2.28	4.53	7.42
April	7.58	5.69	4.23	5.44	5.72	2.23	.92	10.89	5.28
May	11.20	12.66	10.32	6.43	3.51	1.62	5.94	1.95	5.44
June	3.64	7.30	11.80	.81	7.87	7.43	5.20	4.54	6.19
July	2.91	13.45	18.37	10.34	7.41	4.10	12.08	10.72	9.80
August	6.65	5.93	8.47	14.43	8.13	6.47	3.23	6.47	7.13
September	18.31	4.21	8.87	10.14	9.79	5.39	3.95	6.23	8.09
October	3.00	1.30	8.15	2.86	3.07	3.30	.65	3.88	2.60
November	7.08	1.06	1.90	.43	7.87	2.65	4.71	4.68	4.13
December	4.62	2.67	1.52	3.69	7.37	4.23	6.82	3.55	5.37
Total	73.39	72.56	90.43	74.24	86.69	52.07	55.59	70.01	70.43

Results and Discussion

Although measurable growth occurred throughout the year, most of it was between March 1 and October 1. This period was defined as the growing season. Elongations during the 1958, 1959, and 1961 growing seasons are shown in figures 1-3 for the six sample saplings. For convenience, the length of the terminal growth was plotted monthly rather than weekly. Little resolution was lost as a result.

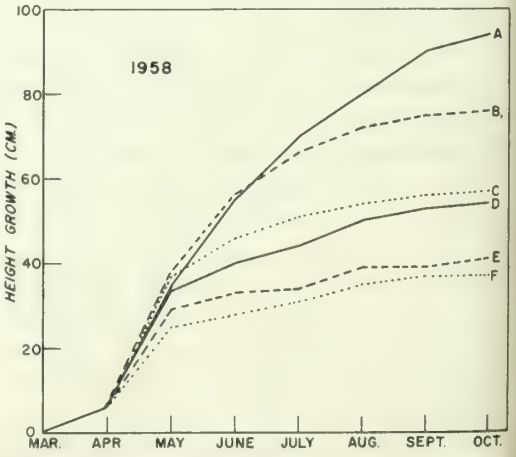

Figure 1.—*Cumulative height growth of six longleaf saplings during the growing season of 1958 (prior to release and fertilization).*

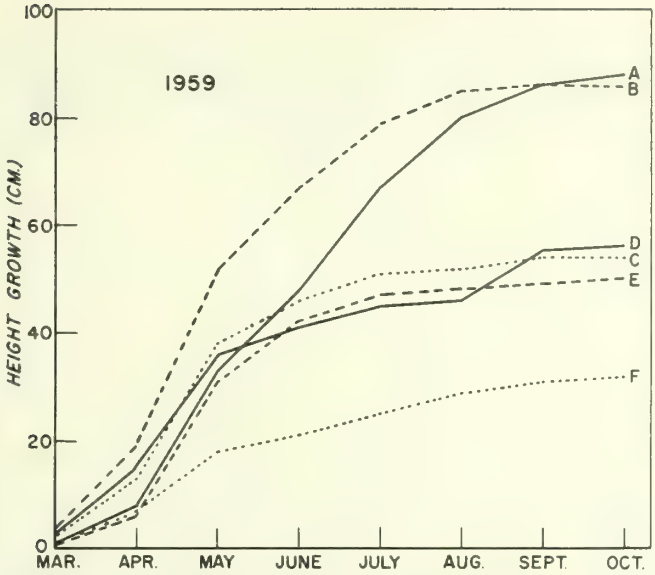

Figure 2.—*Cumulative height growth of six longleaf saplings during the growing season of 1959 (prior to release and fertilization).*

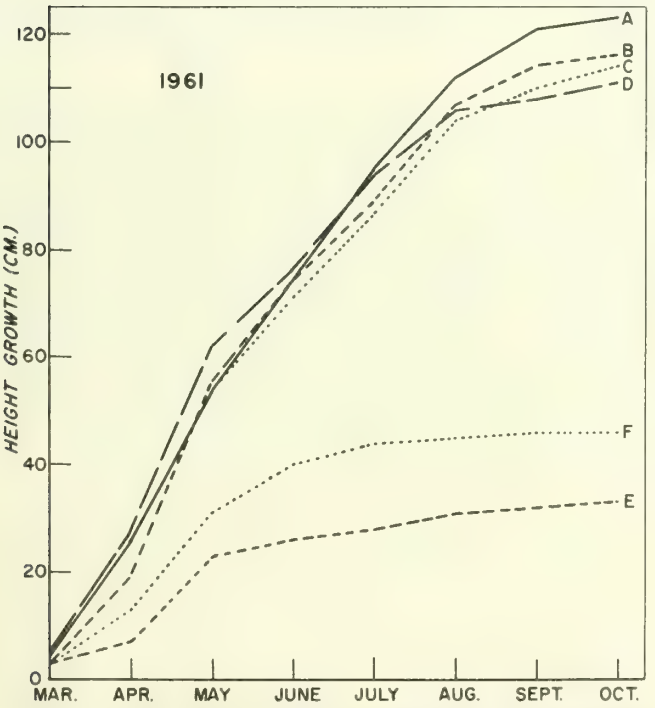

Figure 3.—*Cumulative height growth of six longleaf saplings during the growing season of 1961. Trees A, C, D, and F were released and fertilized; B and E are controls.*

During the spring, when growth was most rapid, some saplings grew as much as 70 mm. per week. Amounts of elongation between November 1 and January 1, by tree, were:

Tree	1958-59	1959-60
	Mm.	*Mm.*
A	3	3
B	4	3
C	1	2
D	2	2
E	3	4
F	1	2

Competition indices for the sample trees before release were:

Tree	Competition index
A	1.6
B	3.4
C	2.5
D	9.0
E	11.6
F	23.9

The shapes of the growth curves were remarkably similar for 1958 and 1959. Trees A and B elongated rapidly throughout most of the growing season. The other trees grew about as much as A and B during the spring flush but much less late in the season.

In 1961, after releasing and fertilizing, trees C and D grew much faster than previously. In both 1958 and 1959 they elongated about 35-40 cm. by May 1—about the end of the spring growth flush. In 1961 they grew about 55 cm. in the same time. The big increase in elongation, however, came later in the season. Summer growth averaged 18 cm. in 1958 and 1959, and 57 cm. in 1961.

Release and fertilization caused little change in the growth of tree A. It grew more in 1961 than it had in either 1958 or 1959, but so did tree B which was not released. Evidently, the indices were correct in indicating that neither tree A nor B suffered much from competition. Tree C had a low competition index but responded markedly to treatment. Tree F, which had severe competition, did not respond well.

Elongation was continuous throughout most of the growing season in all years for trees A and B, and in 1961 for trees C and D. A more sporadic growth pattern was obtained with tree E, and with C and D prior to release. These trees grew rapidly in the spring,

then slowly and intermittently throughout the rest of the growing season.

Total height growths per tree for the years 1962, 1963, and 1964 were:

Tree	1962	1963	1964
	Cm.	*Cm.*	*Cm.*
A	85	107	146
B	94	116	119
C	82	82	116
D	111	110	136
E	36	40	24
F	62	42	31

Tree D continued to show effects of release and fertilization by making as much growth as the two rapidly growing trees, A and B. Tree F never did respond appreciably, and in 1964 it put out a number of apical shoots.

Most of the saplings demonstrated the capacity to grow continuously from February to October if environmental conditions were favorable.

Winter-Bud Elongation of Longleaf Pine

Methods

To determine how the bud elongates to form a shoot, it was necessary to make permanent marks at intervals along the axis of the dormant bud, then periodically measure between the marks to determine where, when, and how much elongation had taken place.

In a first attempt, India ink marks were made at 1-cm. intervals along the axis of the dormant buds, but unfolding of the bud scales during bud elongation disrupted the markings. Pins were placed through the dormant bud, but this too was unsatisfactory because the scales held the pins while the buds elongated. A satisfactory procedure was developed in which two shallow incisions were cut with a razor blade directly opposite each other along the length of the bud. Number 0 stainless steel pins were inserted through the bud in the incisions at the desired intervals. The pins did not pass through any bud scales, and their movement with elongation of the bud was not impeded. Cutting the bud scales produced unequal tensions which caused the buds to bend. An additional incision on each side of the bud, midway between the original incisions, allowed the bud to grow straight.

Four longleaf saplings were pinned on January 20, 1960. They were about 4 feet tall and were growing in an abandoned field. The uppermost pin was placed just below the curved shoulder of the bud tip, and the lowest just below the base in the previous year's wood. The distance between the two pins was then divided into five equal parts by placing four pins at equal intervals between the first two. In addition, terminal buds of 10 other saplings were divided by placing the pins 5 mm. apart. To prevent injury to the apical meristem, no pins were placed above the rounded shoulder of the bud tip. All buds were measured weekly.

Results and Discussion

Almost no measurable elongation took place in the basal bud section. In the remaining four sections, elongation started simultaneously and proceeded at similar rates until growth culminated in each section. Growth in the second section culminated after 42 days, in the third after 49 days, the fourth 63 days, and the fifth 70 days. Elongation of the fifth section was complete in 98 days. Growth of the various sections of the winter bud are shown in figure 4.

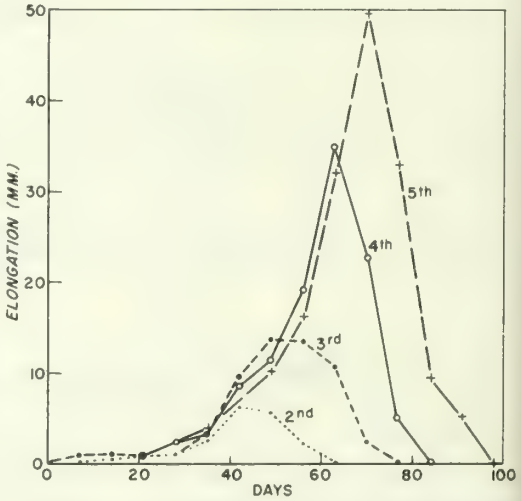

Figure 4.—*Periodic rate of elongation in sections of the longleaf bud.*

Average final length of each section—as a percent of total length of the shoot—was:

Section	Final length	Range
First	0.2	0.0- 0.5
Second	3.3	2.4- 4.3
Third	13.1	11.4-16.5
Fourth	28.6	27.0-30.2
Fifth	54.8	51.9-57.2

The sections averaged 13.25 mm. in length when the pins were placed. When growth was complete, the fifth sections averaged 173 mm. in length. Even greater increases were found in some of the individual sections marked at 5-mm. intervals. The greatest length attained by a 5-mm. section was 100 mm.—a 20-fold increase.

The growth rate of the tip was not shown because it was impossible, by macroscopic examination, to determine how much elongation could be attributed to lengthening of the winter bud, and how much was due to formation of the bud for the second flush. In any case, tip sections did not elongate much: the top pin averaged only 27.8 mm. below the base of the second flush after the elongation of the first flush was completed. In those buds pinned at 5-mm. intervals, tips started elongating 42 days after the 5-mm. sections immediately below the tip.

Growth Flushes in Longleaf Pine

It is commonly accepted that height growth is intermittent *(8)*. Kramer *(7)* found intermittent elongation in loblolly seedlings, even when they were grown in a controlled environment. In the Deep South, however, the results just described, as well as the data of Eggler *(3)* show that continuous growth in length can occur throughout the growing season with longleaf pine.

To analyze the nature of elongation, three longleaf saplings in an abandoned field were released, mulched, and fertilized in the winter of 1959-60 as in the first study of this paper. They were then measured weekly throughout the 1960 growing season. Each new bud was pinned as soon as its formation could be recognized by the sterile cataphylls. Measurements are plotted in figure 5.

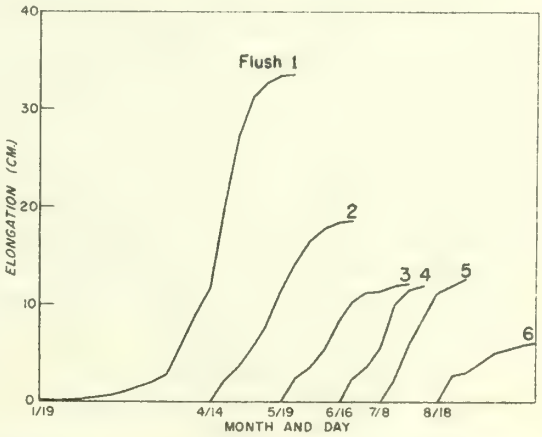

Figure 5.—*Average cumulative elongation of each growth flush and formation of the winter bud of longleaf pine saplings in one season.*

Results and Discussion

The first flush of growth has a typical sigmoid curve with maximum rate of elongation occurring in April. Curves for the second flush and subsequent ones are not sigmoid; they fail to show the initial lag, because the buds of new flushes were not marked soon enough to detect slow initial growth.

The second flush was marked as starting on April 14, when the first flush was making its most rapid elongation. The third flush appeared to start growing on May 19, just before the first flush stopped. The pattern was the same for each succeeding flush throughout the growing season. Thus, two flushes were rapidly elongating at the same time from mid-April until late July.

The first flush attained the greatest length, followed by the second flush. The third, fourth, and fifth flushes attained about the same final lengths. While this is the typical pattern for longleaf pine, it is not uncommon to find individual trees on which, in a given year, the second flush is longer than the first.

Number of Flushes

The number of growth flushes made by pine during a growing season is not predetermined. In southern pine saplings, it is, in general, positively correlated with vigor, and some races of the southern pines can be made to add flush after flush throughout the year if temperature and day length are properly controlled *(2)*.

Still, we know very little about the factors controlling the number of flushes made by trees in the field. Some insights can be obtained from the growth responses of saplings which are girdled and/or defoliated.

Methods

Old foliage was removed and girdles were placed near the ground line on 6-year-old longleaf saplings in 1961. There were four treatments:

No girdle, needles present (control)
No girdle, needles removed
Girdle, needles present
Girdle, needles removed

Each of the treatments was assigned to 34 trees and applied in early spring.

Total height growth and number of flushes per tree were determined at the end of the growing season. Total length of the spring flush was measured, but individual lengths of later flushes were not. The study is described in detail in an earlier paper where the effects of the treatments on the elongation of the spring flush are reported *(1)*.

Results and Discussion

Removing the old needles reduced summer growth in length by about 50 percent but had little effect on number of flushes. Girdling,

on the other hand, reduced the number of flushes by about one. Summer elongation (i. e., total height growth for the season minus length of the spring flush) and number of summer flushes (total flushes for the season minus one) averaged for each treatment were:

Treatment	Summer growth	Summer flushes
	Mm.	*No.*
No girdle, needles present (control)	683	3.8
No girdle, needles removed	372	3.5
Girdle, needles present	367	2.5
Girdle, needles removed	166	2.3

Values connected by the same vertical line do not differ at the 0.05 level of confidence.

Ungirdled saplings without needles grew 372 mm. and averaged 3.5 flushes, while girdled saplings with needles grew 367 mm. but averaged only 2.5 flushes. Therefore, length is not entirely dependent upon number of flushes. Because the summer flushes were not measured individually, it was impossible to determine if the reduction in growth caused by girdling was due to the smaller number of flushes or to an effect on elongation *per se*. Some indication of the relation between number of flushes and length is available from another group of longleaf saplings from the same plantation. Height growth was analyzed for the main stems of 40 dominant saplings that averaged about 20 feet tall. The trees were cut in the fall of 1964 and the length of each flush measured for the years 1961 through 1964. Correlations between the number of flushes of summer growth and the length of summer growth were determined for each of the 4 years:

Year of comparison	Correlation coefficient
1961	0.67*
1962	.45*
1963	.46*
1964	.55*
Average (from Z transformation)	.53

The variation in length accounted for by the variation in number of flushes ranged between 21 and 45 percent. Thus, although there is normally a relationship between length and number of flushes the girdling-defoliation study shows that growth in length is not necessarily controlled by the number of flushes.

Some speculation about the results of the girdling-defoliation study is in order until more complete information is available. Re-

*Denotes statistical significance at a probability of 5 percent.

moving the needles reduced growth by about 50 percent. Loss of this amount of foliage obviously reduced the amount of available photosynthate; therefore, it appears that growth in length is strongly influenced by the amount of photosynthate available. Needle removal only slightly affected the number of flushes, while girdling reduced the number by one. Therefore, it appears that something is more important than amount of photosynthate in controlling the number of flushes.

Girdling caused more late-season mortality than did needle removal. It undoubtedly severely reduced root growth and new xylem formation at the girdle, which could have caused internal water deficits. The reduction in number of flushes may have been caused by high water deficits. Indeed, Zahner *(13)* showed that drought reduced the number of flushes produced by loblolly pine. Since the widely differing amounts of available photosynthate resulting from the defoliation treatments had little effect on number of flushes, the most probable effect of drought appears to be directly on the shoot rather than indirectly through a reduction of photosynthesis.

Literature Cited

1. Allen, R. M.
   1964. Contributions of roots, stems, and leaves to height growth of longleaf pine. Forest Sci. 10: 14-16.

2. Allen, R. M., and McGregor, W. H. D.
   1962. Seedling growth of three southern pine species under long and short days. Silvae Genet. 11: 43-45.

3. Eggler, W. A.
   1961. Stem elongation and time of cone initiation in southern pines. Forest Sci. 7: 149-158.

4. Forward, D. F., and Nolan, N. J.
   1964. Growth and morphogenesis in Canadian forest species. VII. Progress and control of longitudinal growth of branches in *Pinus resinosa* Ait. Can. J. Bot. 42: 923-950.

5. Keinholz, R.
   1941. Seasonal course of height growth in some hardwoods in Connecticut. Ecology 22: 249-258.

6. Kozlowski, T. T., and Ward, R. C.
   1961. Shoot elongation characteristics of forest trees. Forest Sci. 7: 357-368.

7. Kramer, P. J.
1957. Some effects of various combinations of day and night temperatures and photoperiod on the height growth of loblolly pine seedlings. Forest Sci. 3: 45-55.

8. Kramer, P. J., and Kozlowski, T. T.
1960. Physiology of trees. 642 pp. N. Y.: McGraw-Hill Book Co., Inc.

9. Tepper, H. B.
1963. Leader growth of young pitch and shortleaf pines. Forest Sci. 9: 344-353.

10. Wakeley, P. C., and Marrero, J.
1958. Five-year intercept as site index in southern pine plantations. J. Forest. 56: 332-336.

11. Walters, J., and Soos, J.
1963. Shoot growth patterns of some British Columbia conifers. Forest Sci. 9: 73-85.

12. Wilcox, J. R., and Farmer, R. E.
1968. Heritability and C effects in early root growth of eastern cottonwood cuttings. Heredity 23: 239-245.

13. Zahner, R.
1962. Terminal growth and wood formation by juvenile loblolly pine under two soil moisture regimes. Forest Sci. 8: 345-352.

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Hydrologic Effects of Prescribed Burning on Abandoned Fields In Northern Mississippi

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Hydrologic Effects of Prescribed Burning on Abandoned Fields In Northern Mississippi

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Prescribed burning is frequently the cheapest way to prepare a site for direct seeding of pines. It is also often used to improve forage for cattle or to increase the supply of game-food plants. In the absence of specific data, however, land managers are apprehensive about burning in areas where there is danger of increasing erosion and surface runoff. This paper reports the 3-year effects of single burns on two grass-covered watersheds in northern Mississippi, one of the most erosive areas in the South.

Rainfall, runoff, and sediment were monitored on three small watersheds from 1960 through 1963. Two watersheds were then burned and loblolly pines were planted on them. The third was maintained as an untreated control. Linear regressions relating conditions on each treated catchment with those on the control were computed from the pretreatment records. These relationships were the basis for evaluating post-treatment hydrologic behavior. Changes in the composition and distribution of the vegetation were observed before and after treatment.

The long-term objective of the study described is to determine the hydrologic effects of converting grassy fields to loblolly pine. It was also possible to measure the effects of burning because the fire was expected to increase surface runoff, and the pine eventually to decrease it.

STUDY WATERSHEDS

The study area is on the Upper Coastal Plain in northern Mississippi. Mean annual precipitation of 53.3 inches is fairly well distributed throughout the year. The mean daily temperature is 63.1° F. Average dates of the first and last frosts are November 7 and March 28; thus, length of the frost-free season averages 224 days.

[1] Principal Hydrologist at the Forest Hydrology Laboratory, Oxford, Miss. The Laboratory is maintained by the Southern Forest Experiment Station in cooperation with the University of Mississippi. The study was installed with the cooperation of the Soil Conservation Service.

Northern Mississippi is underlain by deep unconsolidated strata of sands and clays. Upland soils are typically sandy, but the study area is on the eastern fringe of a loessial blanket. Loessial remnants commonly occupy ridges and upper slopes. Farming began about 1830, but many sloping fields were abandoned due to progressive erosion.

The three watersheds are typical of many abandoned fields in northern Mississippi. Grades range from 2 to 6 percent along ridges and up to 40 percent on slopes. Watershed I has all loessial soils, predominantly Providence silt loam. It drains 2.65 acres and has a 37-foot range in elevation from the watershed divide to the measuring flume.

Watershed II has Providence silty clay loam on the upper slopes, which make up 64 percent of the drainage, and Ruston sandy loam on the remainder, the lower slopes. It drains 2.62 acres and has a 44-foot range in elevation.

Watershed III has Providence silty clay loam on the rim and upper slopes, which comprise 25 percent of the 2.43 acres that are drained. Ora sandy loam on midslopes and Ruston sandy loam on lower slopes make up the other 75 percent of the area. The range in elevation is 49 feet.

The loessial soils on the watersheds are characterized by a shallow fragipan, which tends to perch water during winter and early spring. Similar loessial soils are found along the Mississippi River from Illinois southward. The upland soils developed from Coastal Plain materials typically have a sandy-clay B horizon. Ruston and Ora soils are important in all the Southern States.

All three catchments were severely sheet-eroded prior to abandonment. Both Watersheds II and III also had gully walls with exposed mineral soil. Small open catchments without gullies would have been preferred, but such watersheds are rare in the area.

Prior to burning, the vegetative cover consisted primarily of bluestem grasses (*Andropogon* spp.), whose basal area covered an average of 14.5 percent of the catchment areas in 1961 (fig. 1). Basal areas were determined just above the ground surface along linear transects.

METHODS

Watershed Treatment

Watersheds I and III were backfired on December 18, 1963. The fires burned hot due to a variable 5- to 10-m.p.h. wind. No runoff occurred during the remainder of 1963. To determine the long-term effects, 1-0 loblolly seedlings were planted on the two burned water-

Figure 1.—*Watershed I prior to the burn, December 1963.*

sheds on March 11, 1964. Trees were planted with dibbles at a 6- by 6-foot spacing. The planting operation and the development of the pines through 1966 could have had little hydrologic effect.

Annual rainfall on the watersheds averaged 65.93 inches in 1964, 41.37 in 1965, and 49.77 in 1966. Deviations from the long-term mean were +12.63, —11.93, and —3.53 inches. Thus, after treatment there was a wet year, a dry year, and 1 year with nearly average rainfall. Average monthly rainfall and monthly runoff during the study period are given in tables 7 and 8 in the Appendix.

Instrumentation

Runoff from the watersheds is measured in 3-foot H-flumes equipped with water-stage recorders *(6)*. Deposited sediment is collected in concrete approach sections. Samples for suspended sediment determinations are obtained with a Coshocton wheel sampler *(3)*.

The three catchments are within a ¼-mile radius. A recording rain gage is located near the center of the study area and three nonrecording gages are on each watershed.

Calibration

The paired watershed approach was taken in this study. Analytical methods for determining the adequacy of calibration of annual

discharge from paired watersheds have been presented by Wilm *(8, 9)* and extended by Kovner and Evans *(2)*. Reinhart *(4)* applied these methods to monthly and seasonal yields and to peak and low flows. Runoff from the study watersheds was largely ephemeral and main reliance was placed on calibration relationships for individual events. The adequacy of such calibrations has been reported *(7)*.

The measurements were begun in 1957. Comparisons of regressions developed for stormflow volumes collected during each of the years 1957 through 1962 indicated that the relationships among watersheds were changing. The changes were due partly to natural improvement of the vegetation and partly to removal of scattered and small patches of scrub oaks to obtain a uniform grass cover. The amount of bare soil decreased from an average of 60 percent of the watershed areas in June 1957 to 7 percent in August 1961 (table 1). The cover changed most during the first few years as grasses and grass litter progressively covered bare soil.

Table 1.—*Changes in ground cover prior to treatment*

Cover classes	Watershed	June 1957	August 1961	Change 1957-1961
		– – *Percent of ground surface* – –		
Grasses	I	8	15	+ 7
	II	12	15	+ 3
	III	6	14	+ 8
Forbs	I	1	1	0
	II	1	1	0
	III	2	1	– 1
Litter	I	35	83	+48
	II	36	79	+43
	III	17	69	+52
Bare soil	I	55	0	–55
	II	51	5	–46
	III	75	15	–60
Miscellaneous	I	1	1	0
	II	0	0	0
	III	0	1	+ 1

Further comparisons, dropping years stepwise starting with 1957, indicated that the individual regressions for 1960, 1961, and 1962 did not differ significantly. It was then decided to extend the calibration period from 1960 through 1963.

Initially, three watersheds were selected with the expectation that a satisfactory calibration relationship would be developed for at least one pair, one of which would be treated. It soon became

apparent that the hydrologic behavior of Watershed I differed appreciably from that of II and III. Wide variations in runoff with respect to Watersheds II and III meant that relatively large changes would be required to demonstrate treatment effects. As originally conceived, Watershed I would have been abandoned and either II or III randomly selected for treatment. This procedure would have fully met statistical requirements. However, unpublished results of another study in the area indicated almost complete elimination of runoff from watersheds 20 years after pine planting. Thus, interest was renewed in the major treatment applied to watersheds with hydrologically shallow soils. It was decided to treat two watersheds identically to provide additional information from the study.

The selection of the control (untreated) watershed was on the basis of soils. Watershed I with all loess soils and Watershed III with primarily Coastal Plain soils were treated identically. Watershed II, intermediate with respect to soils, served as the common control.

Pretreatment relationships among watersheds were developed for the volumes of stormflow and two measures of their distribution—instantaneous peak discharges and the portions of stormflow volumes estimated as overland flows. All events which produced runoff on either the control watershed or a watershed to be treated were included in the stormflow volume analyses. A storm was defined as a precipitation event bounded by rainless intervals of at least 6 hours. The calibration and post-treatment equations for the three variables are summarized in tables 9, 10, and 11 in the Appendix.

Analyses

The linear regression model to describe relationships between watersheds during the calibration period is $Y = a + bX$. The calibration regressions were compared by covariance analysis with the regressions developed from data collected during each year after treatment. The null hypothesis is that the two regressions are estimates of the same general equation. If this hypothesis is rejected, the conclusion is that the relation between phenomena on the control watershed (X) and on a treated watershed (Y) has changed, and that two equations are required to describe the relations before and after treatment.

Covariance analyses can determine whether the change is some function of X or is best expressed as a constant for all values of X *(1)*. The first step is to test for differences in slope. If slopes differ, the magnitude of change varies with X.

When slopes were found to be significantly different, each individual measurement after treatment was subjected to a t-test, and the probability of the magnitude of the change determined. Repeated

use of the t-test, comparing successive post-treatment observations against the same prediction equation, fails to meet statistical standards because requirements for independence are not met. However, such comparisons are informative and were made. Where used, the t-tests were for increases only. Thus, only one end of the probability curve was considered.

If the slopes of the equations do not differ, differences in level can be tested. Here again, since the critical value for testing equal levels cannot be precisely determined, the hypothesis of equal slopes cannot be tested without some probability of error. However, to aid interpretation where a change in level was indicated, the two equations were adjusted to a common slope and the average change determined. The average change was also expressed as a percentage of the pretreatment mean to aid comparisons among post-treatment years.

Previous work has shown that it is desirable to base regressions on about 30 values *(7)*. When there were too few values to adequately define a regression for a particular year, regressions were developed from the combined data for 2 or 3 years. All testing was at the 5-percent level of confidence.

Where variances of regressions differed significantly and a change in level was indicated, a conservative test was applied. The largest variance and its degrees of freedom were used in the F tests for differences in slope and level. While true differences in pre- and post-treatment variances might exist, none of the conclusions regarding change in level was altered as a result of this procedure.

Ratios of sediment yields before and after treatment were compared. The ratios are for annual yields and average annual concentrations of sediment per unit of runoff.

TREATMENT EFFECTS

Runoff

Stormflow volumes.—Stormflow volumes from Watershed III averaged 0.09 area-inch higher than predicted during 1964—an increase of almost 50 percent of the pretreatment mean. The increases were smaller, but continued significant through the second and third years after treatment (table 2). The increases for all 3 years were independent of the volumes of stormflow from the control watershed.

The average volume of runoff per storm from the control in 1964 and 1965 closely approximated the mean for the calibration period; average runoff per storm from the control in 1966 was almost twice the calibration mean.

Table 2.—*Effect of burning on volumes of stormflow—Watershed III*

Year	Events	Average change per event	Average change
	Number	*Area-inches*	*Percent* [1]
1964	34	+0.089*	47.5
1965	18	+ .041*	21.7
1966	12	+ .044*	23.3
1964-66	64	+ .067*	35.6

[1] Percent of pretreatment mean.

* Statistically significant at 5-percent level.

Calibration and post-treatment regressions for Watershed I did not differ significantly. Presumably, soil characteristics rather than cover exerted the dominating influence on runoff from this catchment.

Overland flow.—Overland flow was defined as the volume of stormflow represented by the part of a hydrograph above a straight line drawn between the beginning of a rise and the point of maximum curvature on the recession.

Overland flows from Watershed I were significantly greater than predicted in 1965, but not in 1964 or 1966. Since the increases did not diminish after the first year, the most reliable indicator of change was the equation developed from all the data collected during all 3 years after treatment. The average change for the 3 years was 0.086 area-inch, a significant increase equivalent to 23 percent of the pretreatment mean (table 3). While burning did not increase the total volumes of stormflow from these hydrologically shallow soils, it did increase the portion estimated as overland flow.

Table 3.—*Treatment effects on overland flow*

Year	Events	Average change per event	Average change
	Number	*Area-inches*	*Percent* [1]
		Watershed I	
1964	32	+0.062	16.8
1965	15	+ .121*	32.5
1966	11	+ .104	28.0
1964-66	58	+ .086*	23.1
		Watershed III	
1964	33	+ .102*	61.0
1965	15	+ .060*	36.1

[1] Percent of pretreatment mean.

* Statistically significant at 5-percent level.

Overland flows from Watershed III averaged 0.102 area-inch higher than predicted in 1964 and 0.060 area-inch higher than predicted in 1965 (table 3). These average increases were equivalent to 61 and 36 percent of the pretreatment mean. The slope of the regression for 1966 values differed from the pretreatment slope. The comparisons of individual events indicated that overland flow was significantly higher than predicted for five of the 11 events during 1966 (fig. 2).

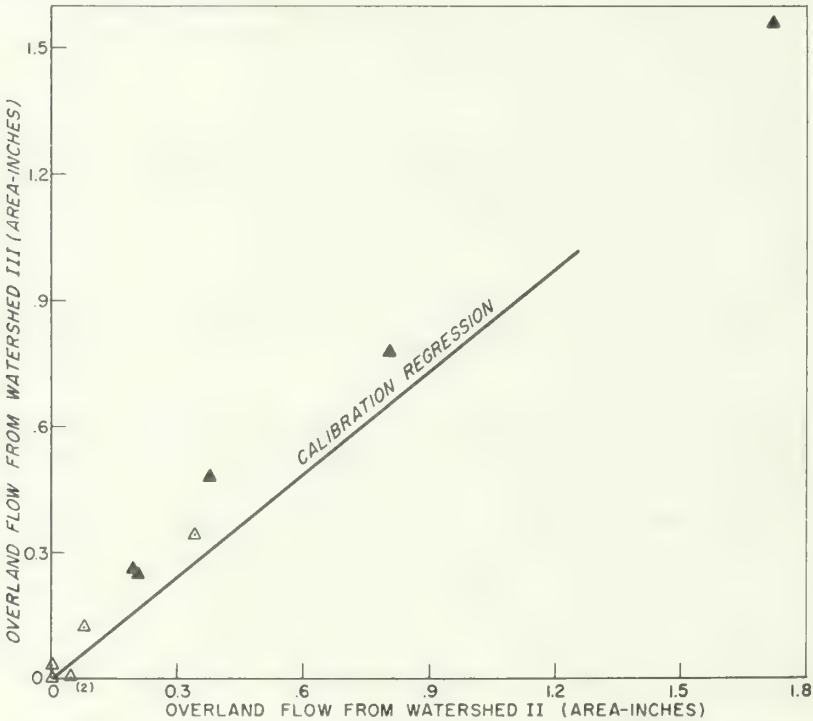

Figure 2.—*How burning influenced volumes of overland flow from Watershed III in 1966. Solid symbols indicate significant departures from predicted values.*

Peak discharges.—Analyses were confined to runoff events which produced instantaneous peak flows $\geq$ 0.10 c.f.s. (cubic feet per second) per acre on the control or a treated watershed.

Instantaneous peaks were significantly higher than predicted on both catchments in 1964. For Watershed I, the average increase of 0.27 c.f.s. per acre was equivalent to 47 percent of the pretreatment mean. Although the volumes of stormflow from this catchment did not increase after burning, the increase in peak flows tends to substantiate the significant increase in the volumes of overland flow. For Watershed III, the average increase in peak flows was 0.69 c.f.s. per acre. The peak flow at the pretreatment mean more than tripled.

Three of the four individual regressions for 1965 and 1966 changed in slope rather than level. The exception was the 1966 equation for Watershed III, which changed in level, but this equation was based on only six events. When the data for 1965 and 1966 were combined, the analyses indicated a significant change in regression slopes for both watersheds. Twenty-four percent of the peak flows from Watershed I during 1965 and 1966 (fig. 3), and 27 percent of those from Watershed III during these years (fig. 4), were significantly higher than predicted.

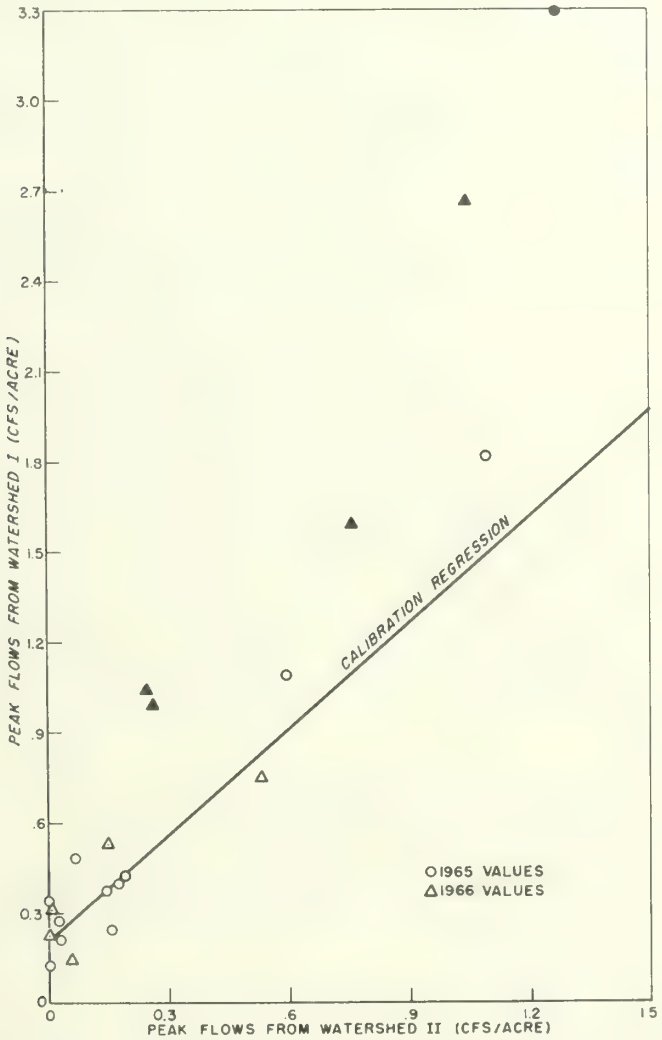

Figure 3.—*How burning influenced peak flows from Watershed I in 1965 and 1966. Solid symbols indicate significant departures from predicted values.*

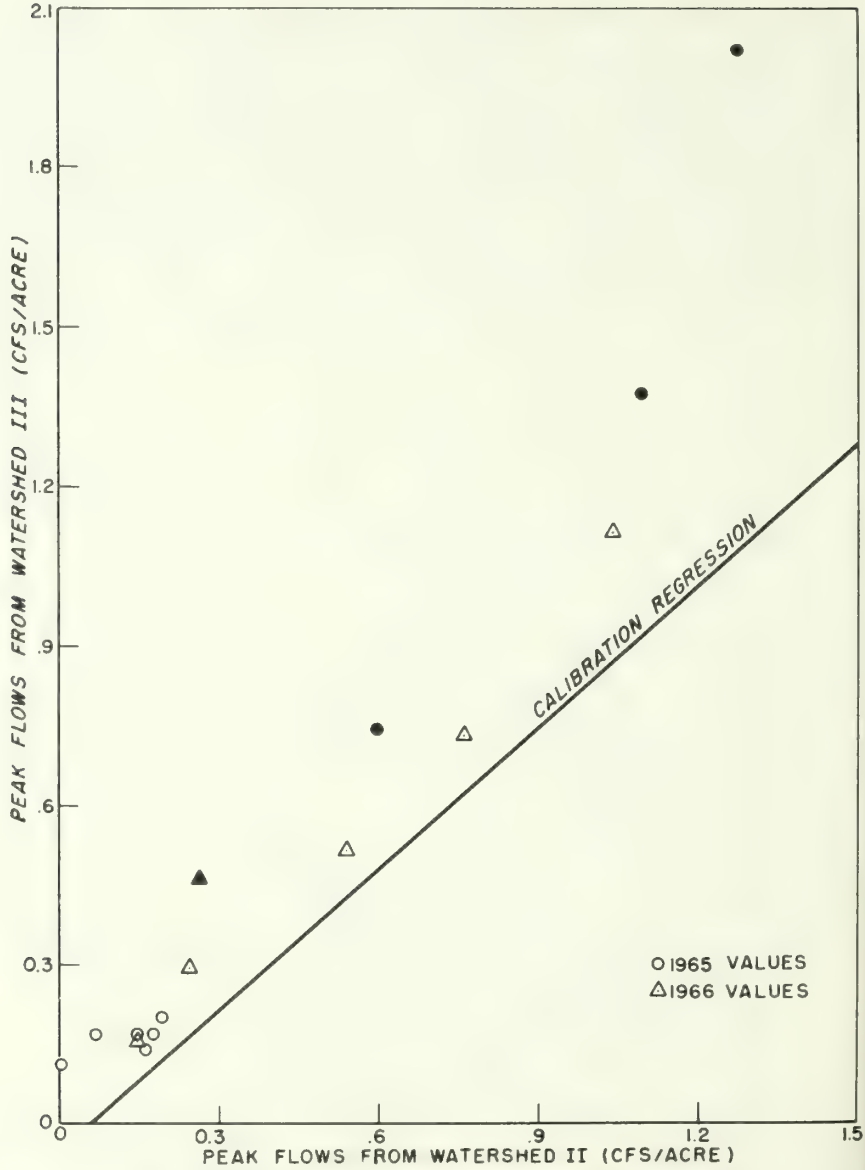

Figure 4.—*How burning influenced peak flows from Watershed III in 1965 and 1966. Solid symbols indicate significant departures from predicted values.*

Sediment

Watershed II, the control, produced the most sediment during the four calibration years (an average of 690 pounds per acre per year) and had the highest concentration of sediment per unit runoff (161 pounds per acre-inch).

During the first 9 months after Watersheds I and III were burned,[2] sediment yields from the control watershed were less than the pretreatment mean. During the same period, yields increased from pretreatment means of less than 100 pounds per acre to ¾ ton per acre from Watershed I, and to almost 3 tons per acre from Watershed III (table 4). The ratio of post- to pretreatment production was 18:1 for Watershed I and 78:1 for Watershed III. Similarly, burning increased the concentration of sediment by a factor of 18 on Watershed I and 44 on Watershed III.

Table 4.—*Sediment yields before (1960-1963) and after burning*

Year and watershed	Production		Concentration	
	Absolute	Post- to preburn	Absolute	Post- to preburn
	Lbs. per acre, ovendry weight	*Ratio*	*Lbs. per acre-inch of runoff*	*Ratio*
1960-1963				
II Control	690 [1] (279-1,089)	.	161 (118-220)	...
I	84 (43-141)	..	7 (6-9)	...
III	74 (26-135)	..	20 (11-35)	..
1964 [2]				
II Control	639	0.9	136	0.8
I	1,542	18.4	126	18.0
III	5,759	77.8	886	44.3
1965				
II Control	281	.4	63	.4
I	88	1.0	7	1.0
III	519	7.0	116	5.8
1966				
II Control	125	.2	25	.2
I	33	.4	3	.4
III	47	.6	10	.5

[1] Range in parentheses.

[2] First 9 months of 1964.

Much of the increase for Watershed III resulted from the reactivation of a small gully. Sufficient vegetation had developed on the gully floor to trap much of the sediment coming from the raw gully bank. The fire removed the vegetation and the sediments moved to the main drainageway and the flume (fig. 5).

Sediment yields during 1965 were low from the control and Watershed I, but continued high from Watershed III. Although yields were low from all three watersheds in 1966, the effects of burning were still apparent.

[2] Postburn data in 1964 limited to the first 9 months. Data after September 28, 1964, during which about one-third of the runoff occurred, were excluded because an alternate method of measuring sediment proved unreliable.

Figure 5.—*After the fire, sediments were no longer trapped by vegetation on the gully floor, February 1964.*

Vegetation

The weight of the vegetation before the burn averaged 4,470 pounds per acre; the weight of the litter, 3,918 pounds per acre (fig. 6) (table 5). The fire consumed the standing vegetation and 56 percent of the surface litter (fig. 7). Further dissipation of litter was anticipated, but the magnitude of this loss was surprising. An additional 28 percent of the preburn weight was lost by October 1964. Thus, the litter weight was reduced by a total of 84 percent during the first year.

Regrowth during the first year after burning averaged about 1 ton per acre. After 2 years the weight of all cover (vegetation plus litter) increased to one-half the level before burning. After 3 years, cover rose to two-thirds of the preburn level.

Of main interest in the composition of cover is the amount of exposed soil. The fires bared the soil on an average of 25 percent of the watershed surfaces, and an additional 14 percent was exposed during the first year after treatment (table 6). Cover was not fully restored to surfaces bared by fire by the end of the third year after treatment.

Restoration of the cover to preburn levels appears to be gradual. A previous study showed that stormflows from Watershed III and

Table 5.—*Weight of vegetation and litter before and after the December 1963 burn and during the recovery period*

Watershed	Pre-burn	Postburn			
		February 1964	October 1964	October 1965	October 1966
	Pounds per acre—ovendry				
Grass and herbs [1]					
I	4,318	0	2,222	2,400	3,470
III	4,623	0	1,617	2,200	2,065
Mean	4,470	0	1,920	2,300	2,768
Litter					
I	4,629	2,239	798	2,485	2,719
III	3,207	1,227	442	1,687	3,163
Mean	3,918	1,733	620	2,086	2,941
All cover					
I	8,947	2,239	3,020	4,884	6,189
III	7,830	1,227	2,059	3,887	5,228
Mean	8,388	1,733	2,540	4,386	5,708

[1] Material 1 inch or more above the soil surface.

Figure 6.—*A dense cover of bluestem grasses covered the watersheds prior to the burn, December 1963.*

Figure 7.—*The fire removed the standing vegetation and over half the litter. Same areas as in figure 6 in February 1964.*

Table 6.—*Composition of cover before and after the December 1963 burn and during the recovery period*

Cover class	Watershed	Preburn	Postburn			
			February 1964	October 1964	October 1965	October 1966
		– *Percent of ground surface occupied* –				
Grasses	I	15	17	19	19	25
	III	13	15	15	16	19
Forbs	I	1	1	5	5	6
	III	1	1	3	4	4
Litter	I	83	49	28	44	53
	III	69	32	25	37	48
Bare soil	I	0	25	43	28	9
	III	16	42	52	40	21
Moss, lichens, other	I	1	8	5	4	6
	III	1	10	5	3	7
Pine litter	I					1
	III					1

he control are strongly correlated with storage opportunity in the upper 6 inches of soil *(5)*. It seems unlikely that burning changed his relationship. Thus, changes probably resulted primarily from an altered soil surface. If there is a sensitive cause and effect relationship between cover and stormflow, treatment effects may extend beyond 3 years.

By October 1966, 30 months after planting, the pine had cast enough litter to occupy 1 percent of the watershed surfaces. The cast needles will accumulate rapidly during the next few years. Thus, any future effects of burning may be lessened by the pine.

SUMMARY

After 4 years of calibration, two small catchments with a native grass cover were burned. The fire consumed the standing vegetation and over one-half the litter. An unburned catchment was maintained as a control.

During the first year after treatment, stormflows from one burned catchment averaged 0.09 area-inch higher than predicted—an increase of 48 percent at the level of the pretreatment mean. The significant increases continued during the second and third years after treatment and were due largely to higher volumes of overland flow. The average instantaneous peak flow was tripled the first year, and 27 percent of the peaks during the second and third years were significantly higher than predicted.

Identical treatment on a catchment with a fragipan soil did not change the volumes of stormflow, but significantly increased peak discharges and that part of stormflows estimated as overland flow. These changes also persisted through the third year. Soil characteristics, rather than changes in cover, apparently determine the stormflows from this catchment, which has hydrologically shallow soils.

During the first year after burning, sediment production increased from preburn means of less than 100 pounds per acre to ¾ ton from one catchment and to almost 3 tons from the other. The tons came mainly from a small reactivated gully. Sediment yields from burned catchments also remained high in relation to those of the control during the second and third years.

The fire bared one-fourth of the watershed surfaces, and postburn dissipation of the remaining litter increased the proportion of bare soil to 40 percent. Cover was not restored to preburn levels in 3 years.

The results show that relatively small changes in cover can greatly influence the hydrologic performance of small headwater catchments.

LITERATURE CITED

1. Freese, F.
   1964. Linear regression methods for forest research. USDA Forest Serv. Res. Pap. FPL-17, 136 pp. Forest Prod. Lab., Madison, Wis.

2. Kovner, J. L., and Evans, T. C.
   1954. A method for determining the minimum duration of watershed experiments. Amer. Geophys. Union Trans. 35: 608-612.

3. Parsons, D. A.
   1955. Coshocton-type runoff samplers. USDA Agr. Res. Serv. ARS-41-2, 16 pp.

4. Reinhart, K. G.
   1958. Calibration of five small forested watersheds. Amer. Geophys. Union Trans. 39: 933-936.

5. Thames, J. L., and Ursic, S. J.
   1960. Runoff as a function of moisture-storage capacity. J. Geophys. Res. 65: 651-654.

6. USDA Agricultural Research Service.
   1962. Field manual for research in agricultural hydrology. *In* USDA Agr. Handbook 224, pp. 22-34.

7. Ursic, S. J., and Popham, T. W.
   1967. Using runoff events to calibrate small forested catchments. Fourteenth Congr. Proc., Int. Union Forest. Res. Organ., vol. 1, pp. 319-324.

8. Wilm, H. G.
   1944. Statistical control of hydrologic data from experimental watersheds. Amer. Geophys. Union Trans. 1943: 618-622.

9. Wilm, H. G.
   1949. How long should experimental watersheds be calibrated? Amer. Geophys. Union Trans. 30: 272-278.

APPENDIX

Table 7.—*Average rainfall by month during study period* [1]

Month	1960	1961	1962	1963	1964	1965	1966
	Inches						
January [2] (5.04)	5.33	0.76	6.40	1.33	4.45	4.35	2.85
February (4.22)	3.67	8.20	7.42	2.66	3.04	8.98	8.48
March (5.71)	5.84	12.87	3.82	5.46	9.09	9.10	1.72
April (4.88)	2.05	2.63	5.89	6.50	9.95	1.15	7.02
May (4.38)	2.76	3.75	1.73	2.16	1.61	2.70	7.08
June (4.34)	3.56	2.13	7.07	2.05	1.89	.74	2.33
July (4.26)	.45	2.93	4.08	9.58	8.94	2.08	3.11
August (3.61)	2.49	3.33	1.54	3.09	6.41	3.73	1.26
September (3.32)	3.93	1.60	3.75	3.38	5.36	4.22	5.15
October (2.98)	4.76	1.49	1.53	0	2.26	.86	2.34
November (4.54)	3.15	10.18	2.26	3.89	4.47	1.37	1.87
December (6.02)	4.53	10.62	2.23	5.30	8.46	2.09	6.58
Totals (53.30)	42.52	60.51	47.70	45.40	65.93	41.37	49.77

[1] Averages for three watersheds.
[2] Long-term means at University, Mississippi, shown in parentheses.

Table 8.—*Runoff by month during study period*

Month	Watershed	1960	1961	1962	1963	1964	1965	1966
		Area-inches						
January	I	1.31	0.00	3.56	0.00	1.09	1.42	0.00
	II	.20	.00	.81	.00	.25	.28	.00
	III	.13	.00	.76	.00	.24	.30	.00
February	I	.95	4.31	4.02	.19	.48	5.30	4.55
	II	.08	1.51	1.92	.01	.02	2.31	2.50
	III	.07	1.26	1.59	.00	.02	2.23	2.21
March	I	2.84	7.45	1.08	2.49	4.11	5.13	.36
	II	.80	4.01	.16	.87	2.15	1.89	.00
	III	.72	3.33	.14	.81	2.31	1.93	.03
April	I	.09	.42	2.89	2.10	3.94	.02	2.70
	II	.00	.06	1.37	.96	1.02	.00	1.33
	III	.00	.01	1.22	.88	2.03	.00	1.31
May	I	.58	.01	.00	.00	.00	.00	2.11
	II	.10	.00	.00	.00	.00	.00	.64
	III	.04	.00	.00	.00	.00	.00	.80
June	I	.06	.00	1.50	.00	.00	.00	.01
	II	.04	.00	.40	.00	.00	.00	.00
	III	.00	.00	.18	.00	.00	.00	.00
July	I	.00	.00	.00	1.12	.85	.00	.00
	II	.00	.00	.00	.05	.08	.00	.00
	III	.00	.00	.00	.03	.72	.00	.00
August	I	.00	.00	.00	.00	1.74	.00	.00
	II	.00	.00	.00	.00	1.19	.00	.00
	III	.00	.00	.00	.00	1.15	.01	.00
September	I	.00	.00	.00	.71	.54	.00	.00
	II	.00	.00	.00	.10	.26	.00	.00
	III	.00	.00	.00	.07	.38	.00	.00
October	I	.07	.00	.00	.00	.00	.00	.00
	II	.15	.00	.00	.00	.00	.00	.00
	III	.00	.00	.00	.00	.01	.00	.00
November	I	2.70	2.77	.00	.00	.70	.00	.00
	II	.08	1.06	.00	.00	.02	.00	.00
	III	.00	.99	.00	.00	.03	.00	.00
December	I	.95	5.71	.00	1.97	5.04	.00	1.34
	II	.21	2.56	.00	.67	2.48	.00	.44
	III	.20	2.16	.00	.75	2.33	.00	.36
Totals	I	7.12	20.67	13.05	8.58	18.49	11.88	11.07
	II	1.66	9.20	4.67	2.66	7.46	4.48	4.93
	III	1.17	7.75	3.89	2.54	9.24	4.48	4.71

Table 9.—*Calibration and post-treatment regressions relating stormflows on the control (X) and treated (Y) watersheds*

Year	Regression	Number of events	Mean yields	
			$\bar{x}$	$\bar{y}$
			– – Area-inches – –	
		Watershed I		
Prediction equation				
1960-1963	$1.62667X + 0.19288$	88	0.16928	0.46824
	$Sy{\cdot}x^2 = 0.03788$, $Sx^2 = 8.27959$, $r = 0.933$			
Post-treatment equations				
1964	$1.51639X + .20485$	35	.21322	.52817
1965	$1.42564X + .30473$	18	.24915	.65993
1966	$1.50220X + .33368$	11	.44788	1.00648
1964-66	$1.51259X + .24863$	64	.26366	.64744
		Watershed III		
Prediction equation				
1960-1963	$0.85605X - 0.00528$	61	.22576	.18798
	$Sy{\cdot}x^2 = 0.00170$, $Sx^2 = 6.44388$, $r = 0.990$			
Post-treatment equations				
1964	$.88372X + .07781$	34	.21949	.27178
1965	$.88422X + .02862$	18	.24915	.24892
1966	$.89541X + .02513$	12	.41056	.39275
1964-1966	$.88189X + .05552$	64	.26365	.28803

Table 10.—*Calibration and post-treatment regressions relating overland flows on the control (X) and treated (Y) watersheds*

Year	Regression	Number of events	Mean yields	
			x	y
			– – Area-inches – –	
		Watershed I		
Prediction equation				
1960-1963	$1.42598X + 0.11963$	81	0.17736	0.37254
	$Sy{\cdot}x^2 = 0.02968$, $Sx^2 = 7.09577$, $r = 0.928$			
Post-treatment equations				
1964	$1.40438X + .18604$	32	.18573	.44688
1965	$1.25811X + .27452$	15	.20683	.53423
1966	$1.48944X + .20489$	11	.34390	.71711
1964-1966	$1.41352X + .20819$	58	.22119	.52085
		Watershed III		
Prediction equation				
1960-1963	$0.81682X - 0.00710$	62	.21285	.16676
	$Sy{\cdot}x^2 = 0.00201$, $Sx^2 = 5.76836$, $r = 0.985$			
Post-treatment equations				
1964	$.88651X + .08115$	33	.18010	.24081
1965	$.90128X + .03550$	15	.20683	.22191
1966	$.89870X + .03787$	11	.34390	.34693

Table 11.—*Calibration and post-treatment regressions relating peak discharges on the control (X) and treated (Y) watersheds*

Year	Regression	Number of events	Mean yields	
			$\bar{x}$	$\bar{y}$
			– – – C.f.s./acre – – –	
		Watershed I		
Prediction equation				
1960-1963	$1.17154X + 0.20914$	47	0.30884	0.57096
	$Sy{\cdot}x^2 = 0.06155$, $Sx^2 = 7.35005$, $r = 0.885$			
Post-treatment equations				
1964	$1.42893X + .40354$	27	.27081	.79051
1965	$2.03313X + .12026$	12	.31314	.75691
1966	$2.05962X + .20672$	9	.34111	.90928
1965-1966	$2.04633X + .15689$	21	.32513	.82221
		Watershed III		
Prediction equation				
1960-1963	$0.87811X - 0.04782$	31	.43652	.33549
	$Sy{\cdot}x^2 = 0.02144$, $Sx^2 = 5.83361$, $r = 0.937$			
Post-treatment equations				
1964	$1.03293X + .58179$	22	.32799	.92058
1965	$1.44694X - .02690$	9	.41181	.56896
1966	$.95422X + .07212$	6	.49949	.54874
1965-1966	$1.30214X - .02103$	15	.44688	.56087

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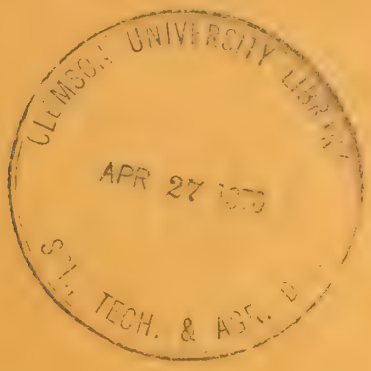

Identifying Juvenile Seedlings In Southern Hardwood Forests

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Southern Forest Experiment Station
Forest Service
U. S. Department of Agriculture

1969

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Identifying Juvenile Seedlings In Southern Hardwood Forests

Louis C. Maisenhelder [1]

The purpose of this paper is to aid foresters, landowners, and naturalists in identifying first-year seedlings of some important trees and a few shrubs in the lower Mississippi River Valley and similar environments of the South. Ability to identify the young seedlings is especially important in forecasting the kinds of useful or weed vegetation that may develop as silviculture is applied.

The species described include 16 found only in alluvial bottom lands, 32 found only in loess bluffs and other uplands, and 20 common in both locations. Several nontree species, such as poison-ivy and snowbell, are included because the seedlings are easily confused with those of commercial trees.

Form and color of cotyledons, leaves, stems, and buds are described and illustrated. Cotyledons never resemble mature leaves, though their form is often useful in identifying the plant during the first few weeks after germination. The first true leaves may not be typical of mature leaves, but by the end of the first year leaf or leaflet shapes tend to resemble closely those of the older trees. Twig and bud characters are shown because they help to identify the plant in the dormant season.

Tables that compare leaves, stems, and buds are included for ashes, elms, hickories, and red and white oaks, because seedlings within each of these genera are often difficult to separate.

Latin and common names follow Little's *Check List of Native and Naturalized Trees of the United States.* Publications that were consulted are listed on page 77, but are not otherwise cited.

[1] Silviculturist at the Southern Hardwoods Laboratory, which is maintained at Stoneville, Miss., by the Southern Forest Experiment Station in cooperation with the Mississippi Agricultural Experiment Station and the Southern Hardwood Forest Research Group.

Green Ash
Fraxinus pennsylvanica Marsh.
Family *Oleaceae*

Bright green leaflets are opposite on light green stem. They resemble those of mature trees. Species is found in low flats, sloughs, and shallow swamps.

Cotyledons.—Medium green with prominent midrib, growing to 1 inch long and ⅛ inch wide 3 days after germination. Lanceolate with blunt, rounded apexes. Persist for several weeks. Difficult to distinguish from American sycamore in cotyledon stage, but usually larger.

Leaves.—First true leaves appear a week after germination as opposite leaflets on elongating stem. Simple, elliptical to ovate with short, dull-pointed apexes and wedge-shaped bases, 1½ to 3 inches long by ½ inch wide; smooth; bright green above, paler below; margins serrate. Closely resemble leaflets of mature compound leaves, which do not develop until last half of first growing season.

At 3 months seedling still has no compound leaves.

Table 1.—*Seedling characteristics of green, pumpkin, and white ash*

Species	Leaves		Stem traits	Buds	
	Color	Margin		Pubescence	Color
Green ash	Bright green above, slightly paler below	Serrate	Olive-green or gray at base. Leaf scars straight or slightly notched at top.	Covered with brown woolly hairs	Brown
Pumpkin ash	Upper surface medium green, slightly paler below	Entire to undulate or finely serrate	Light green at first, becoming dark-green with olive-green streaks at 2½ months. Later brown to gray, still streaked.	Slightly hairy	Brown
White ash	Light green above, slightly paler below	Nearly entire, or with small rounded teeth	Dark purple, becoming brown at maturity. Leaf scars V-notched at top.	Terminal buds: moderate and red-brown. Axillary buds: moderate and brown.	Terminal bud dark brown t black. Axill buds: brown.

Cotyledons 1 day after germination; seed wing protrudes from soil after planting. X 1½

t 2 weeks, persistent cotyledons re-emble those of sycamore but are arger. X 1

Stem.—Bright green at termi-us, shading to olive green or gray base; smooth with a few pale nticels and round in cross section roughout.

Buds.—Blunt, ovoid, 1/16 to ⅛ ch long. Terminal buds slightly nger and sharper pointed than terals. All buds densely hairy.

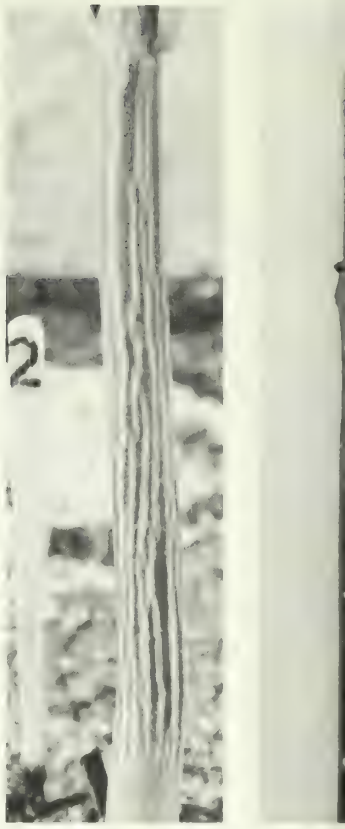
Terminal bud at 1 year; lenticels common on stem. X 4

Pumpkin Ash
Fraxinus profunda (Bush) Bush
Family *Oleaceae*

Leaves and cotyledons are larger than those of most ashes. Olive green stripes are found on basal portion of the stem 2½ months after germination.

Cotyledons.—Plant stem pushes through ground in U-shape and cotyledons emerge and unfold on second day after germination. Upon appearance, single cotyledon about 1⅛ inches long and ¼ inch wide, growing to 2½ inches long by 3/8 inch wide in first month. Linear with blunt, rounded apex and base; dark green above, lighter below, and smooth on both surfaces. Persist on undisturbed stems for as long as 8 months but cease growth after first month.

Leaves.—First true leaves appear within a week after germination as opposite, simple leaflets. Ovate-lanceolate with acuminate apex and wedge-shaped base; margin partly entire, undulate, or finely serrate; medium green above, paler below, both surfaces smooth; 2 to 3 inches long, including petiole. Compound leaves typical of mature trees occur occasionally during first year.



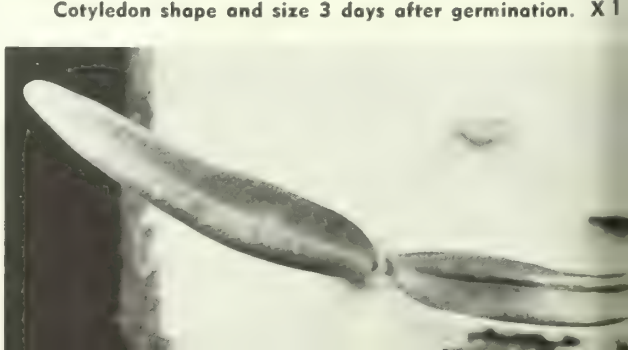
Stems are prominently striped at 10 weeks (left). Lenticels and leaf scars help identify 1-year-old seedling (right). X 2

Stem.—Round, smooth, with a few small, white lenticels. Light green during first month, changing to dark green with prominent olive green stripes on basal portion by 10 weeks. Brown to gray and still streaked at 1 year.

Buds.—Opposite; ovate, obtuse, and flattened. Brown, slightly hairy, and 1/16 to ⅛ inch long.

Seedlings at 10 weeks have simple leaves and persistent cotyledons. X 3/10

Cotyledon shape and size 3 days after germination. X 1



White Ash
Fraxinus americana L.
Family *Oleaceae*

otyledons 1 week
fter germination.
2

Seedling at 5 weeks.
Cotyledons persist for
6 months. X 1

At 1 year terminal bud has
just begun to open. X 2

White ash is difficult to distinguish from ther species, especially green ash, during the irst year. The site—uplands or ridges and igh flats in bottom lands—on which it occurs s the most helpful guide, though not infallible. Green ash is common in low flats, sloughs, and hallow swamps.

Cotyledons.—Dark purple stem emerges in J-shape, and cotyledons appear within a few ays. Elliptical with rounded apexes and bases; ıedium green; single cotyledons are ½ inch ı length. Central vein prominent and light-olored with a few small branches. Persist ı stem for at least 6 months but grow little fter appearance.

Leaves.—Simple; opposite; ovate with short, uminate apex and wedge-shaped base; margin nearly entire or with small rounded teeth. Upper surface light green, paler below; smooth on both surfaces but with a few short hairs around margin. Typical compound leaves first appear after 6 months and have three to five leaflets similar to the first true leaves.

Stem.—Round throughout; dark purple on appearance, later changing to brown; smooth; lenticels pale.

Buds.—Terminals conical to broad-ovoid, obtuse, dark brown to black with red-brown hairs, about ¼ inch long. Axillary buds depressed, globular, brown with brown hairs, smaller than terminal bud.

Baldcypress
Taxodium distichum (L.) Rich
Family *Pinaceae*

At 1 year leaves resemble those of mature trees. X 1/4

Seedlings of this species resemble pines when germinating but are found in or near swamps or on very moist sites. Twigs bear needle-like leaves closely resembling those of mature trees.

Cotyledons.—Light green; linear, resembling pine needles.

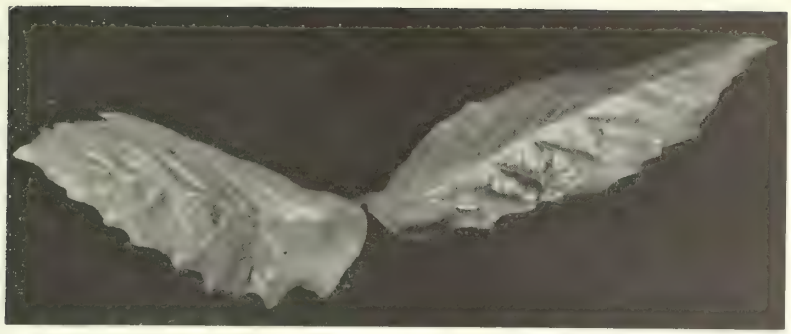
Leaves.—Alternate, in two ranks; linear, short pointed tip entire; sessile; flat. Light green, lustrous, with feathery look.

Stem.—Circular; smooth; red-brown with gray stripes on basal portion after first month. Twigs green to brown, smooth, and often deciduous. Round, slightly elevated twig scars give young stems rough surface.

Buds.—Brown terminal and lateral buds very small and partly submerged in twig.

Stem at 1 year with slightly elevated twig scars. X 1-1/4

American Beech
Fagus grandifolia Ehrh.
Family *Fagaceae*



At 3 weeks characteristic leaves have developed. X 4/5

Large size and truncated triangular shape of the cotyledons are distinguishing characteristics. Juvenile leaves are similar to those of the mature tree.

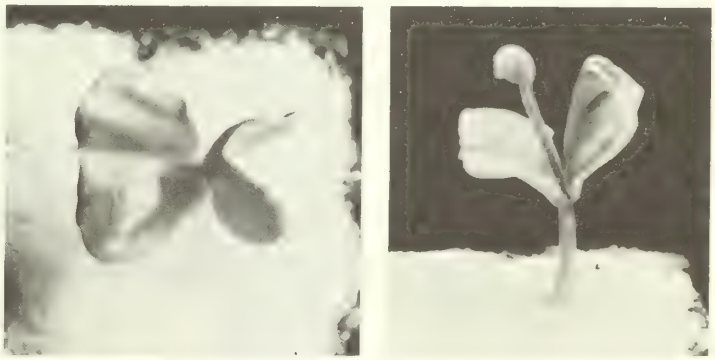
Cotyledons.—Among largest of hardwood species having germination above ground. Sturdy, thick, dark green, shaped roughly like truncated triangle 5/8 of an inch long and 1 inch in breadth. Grow little after unfolding and persist on seedling for a month or more.

Leaves.—First leaves develop on elongating stem about 3 days after germination and in 2 to 3 weeks closely resemble mature beech foliage. Simple, straight-veined ovate-oblong with sharp-pointed apexes, wedge-shaped or rounded bases, and coarsely serrated margins. Pale green when they unfold, covered on lower surface with long silky hairs. After several months, smooth and bluish green above, light yellow below, with tufts of hair in vein axils. Prominent stipules ovate-lanceolate to linear.

Stem.—Olive green with oblong, orange lenticels and coated with easily shed hairs during most of first season. Then becomes smooth, and orange or reddish brown. Round in cross section throughout.

Buds.—Brown; terminal buds cylindrical with prominent scales, sharp-pointed apexes, ½ to 1 inch long and ⅛ inch in diameter; lateral buds ovoid, 1/32 inch long.

Terminal buds at 1 year with stipules and prominent scales. X 4



Cotyledons grow little after emerging (left). First leaves appearing 3 days after germination (right). X 1

Boxelder
Acer negundo L.
Family *Aceraceae*

Buds are opposite on a shiny, bright green stem. Leaflets resemble those of poison-ivy or green ash.

Cotyledons.—Upon first appearance, medium green, lanceolate with bluntly rounded apex, 1 to 1½ inches long by ⅛ inch wide. Grow very little after unfolding, but persist for several weeks.

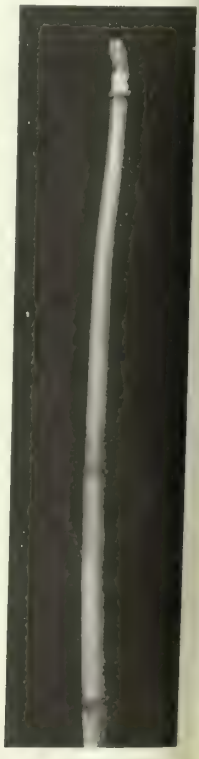
Leaves.—Opposite leaflets appear within first week after germination. Upon unfolding, leaflets densely coated with whitish hairs below and slightly hairy above, later smooth on both surfaces. Simple, ovate to elliptical with blunt, pointed apexes and rounded, often unsymmetrical bases; margins nearly entire or coarsely and irregularly serrate above middle, occasionally slightly lobed. Petioles smooth, slender. Leaflets light green, 1¼ inches long by 5/8 inch wide at 3 weeks. Typical odd-pinnately compound leaves of 3 to 5 leaflets first appear in latter half of first growing season.

Stem.—Smooth and shiny at first, turning bluish (especially near base) toward end of first year. Enlarged base of leaf petioles becomes large, conspicuous scar surrounding the stem when leaves are shed.

Buds.—Terminal buds, though only ⅛ inch long, much longer and more acute than laterals. All buds purplish brown and covered with white hairs.

Juvenile leaf shape and arrangement at 3 weeks. Cotyledons persist for several weeks. X 1

Cotyledons and first leaflets 1 week after germination. X 2



Stem and buds at 1 year. Note difference in size of terminal and lateral buds as well as circular scars left by leaf petioles below each lateral bud. X 2

Common Buttonbush
Cephalanthus occidentalis L.
Family *Rubiaceae*

This species occurs commonly as a shrub on wet sites. Prominent midrib and primary veins are found on dark green leaves with red petioles.

Cotyledons.—Light green; ovate-lanceolate with sharp-pointed apex; cotyledon ⅛ inch long by 1/16 inch wide on appearance. Shed within first month.

Leaves.—Simple; opposite; ovate to ovate-oblong with rounded base and acute to acuminate apex; margin entire. Dark green above, paler below; smooth on both surfaces; stout, light yellow midrib and several pairs of slender primary veins nearly paralleling margin; petioles red and with very small stipules at base. Whorls of three leaves frequently seen on more mature plants but not observed during first year.

Stem.—Circular; olive-green when young, reddish-brown when approaching maturity; lustrous and smooth; marked with a few elongate white lenticels. Leaf scars semicircular and connected by persistent, black stipules.

Buds.—No terminal bud; axillary buds opposite, red-brown, and minute.

Stem and buds at 1 year after germination. X 2

Buttonbush seedling at 3 weeks. X 1. Inset shows cotyledons at 1 week. X 2

At 9 months leaf shape and venation typical. X 1/4

Black Cherry
Prunus serotina Ehrh.
Family *Rosaceae*

Leaves and stem have bitter-almond taste. Juvenile leaves resemble those of the mature plant.

Cotyledons.—Do not appear above ground.

Leaves.—On appearance, light green and smooth. First pair opposite on stem. After several weeks, leaves simple, alternate, oblong or oblong-lanceolate with acuminate apexes and wedge-shaped bases; margins finely serrate, dark green above, slightly paler below; smooth and shiny on both surfaces. Midrib light-colored and prominent below. Lanceolate stipules about ½ inch long at base of leaf petioles that are shed early.

Stem.—At first, pink and smooth, turning reddish to reddish-brown in a few weeks. By midseason, brown at base, changing to light green near terminus; smooth; small lenticels round, white. Cross section round throughout entire length.

Buds.—Broad ovate with obtuse apex; chestnut brown; about ⅛ to ⅜ inch long.

Stem and buds at 1 year show small, white lenticels (left). X 2 Details of both terminal and lateral buds at end of 1-year-old stem (right). X 4

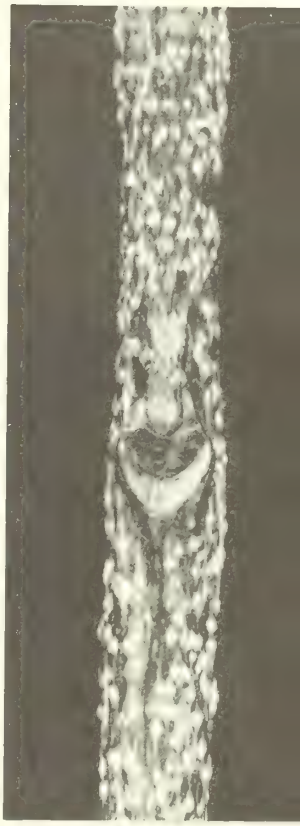
Cotyledons absent 1 week after germination. Leaf shape and arrangement typical. X 2

At 10 weeks leaf arrangement alternate after first pair. X ½

Kentucky Coffeetree
Gymnocladus dioicus (L.) K. Koch
Family *Leguminosae*

Seedling 5 days after germination. X 1

Bark roughened by persistent scales and heart-shaped leaf scars at 1 year. Terminal bud lacking. X 2



Superposed double buds occur frequently. X 4

Pinnately compound leaf has no terminal leaflet. Bark after midyear is roughened by small, persistent scales.

Cotyledons.—Do not appear above ground.

Leaves.—Alternate, pinnately compound with 10 to 12 leaflets opposite a rachis; no terminal leaflet; 2 to 3 inches long by end of first week. Leaflets ovate with acuminate apexes and rounded bases; margin entire; ½ inch long by ¼ inch wide 1 week after germination; bronze-green and shiny when they unfold, becoming medium to dark green above and paler below after a week; smooth on both surfaces. Bipinnately compound leaves characteristic of more mature trees do not develop in first year.

Stem.—Stout; round and smooth with white to orange lenticels; light green on appearance, turning greenish-brown by end of first year. Bark roughened by persistent scales at midyear and by conspicuous, heart-shaped leaf scars in late autumn.

Buds.—Usually partly sunken in small crater; globular; smooth; light brown and about 1/16 inch diameter. No terminal bud; axillary buds frequently occur in pairs, one above the other.

Eastern Cottonwood
Populus deltoides Bartr.
Family *Salicaceae*

For the first few weeks, leaf shape resembles that of mature black willow. Triangular leaves typical of mature trees appear by midseason.

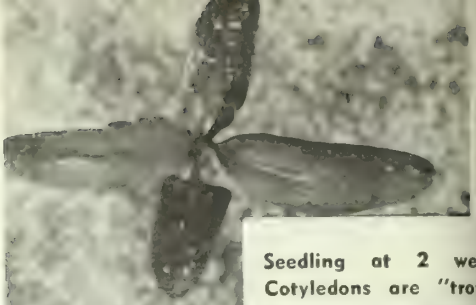
Cotyledons.—Elliptic during first week, with basal portion truncated and slightly notched; during second week, notch disappears, leaving cotyledons trowel-shaped. Smooth; dark green. Persistent for 2 months on red, smooth stem.

Leaves.—True leaves appear at end of first week. At first lanceolate with rounded apexes and wedge-shaped bases; moderately dark green, with entire to partially serrate margins and flat petioles. After several weeks, leaves grow broader, and by midseason some are typically triangular with rounded tooth margins. Smooth, alternate, light green above, slightly paler below.

Stem.—Gray to reddish-brown with prominent elliptic, white lenticels. Stem cross section round near base, becoming angular higher up, especially near terminus.

Buds.—Reddish-brown, ovoid, and acute; lateral buds flatter than terminals. One-half inch or less in length, usually with light resinous coating and triangular leaf scar beneath bud.

Stem and buds at 1 year. Leaf scar triangular-shaped and lenticels prominent, white. X 2



Seedling at 2 weeks. Cotyledons are "trowel-shaped" and leaves entire to partially serrate. X 2

Cotyledons slightly notched at base 1 week after germination. First true leaves appearing. X 3½

At 6 weeks leaves starting to broaden and assume deltoid shape. Cotyledons still attached. X 2

Swamp Cottonwood
Populus heterophylla L.
Family *Salicaceae*

Seedling at 6 weeks. Early leaves vary in shape. Cotyledons still persist. X 1

Stem.—Smooth by end of first year but lightly covered for 2 to 3 months with whitish hairs; olive green to red-brown; a few small, elongated, white lenticels. Stem cross section angular throughout.

Buds.—Red-brown; smooth; dull pointed. Terminal buds ovoid, ⅛ inch long; lateral buds more lanceolate and smaller.

Cotyledons are roughly kidney-shaped. Leaves are egg- or heart-shaped with round teeth and petioles. At first seedlings are easily confused with eastern cottonwood and black willow but are always identifiable by cotyledons and, within a few weeks, by leaf shapes.

Cotyledons.—Oblate with narrow wedge-shaped junction where petiole joins long edge; opposite arrangement on reddish-brown, smooth stem. Medium green above and below; blade ⅜ inch long by ½ inch wide; persist on stem for about 2 months.

Leaves.—First leaves appear within 2 weeks after germination; simple, alternate, with round petioles. For first month ovate to slightly heart-shaped, medium green, with dense covering of deciduous hairs; margins coarsely serrate except on broad base. By midyear have assumed mature characteristics: broadly ovate, sharp-pointed or rounded at apexes, slightly heart-shaped, wedge-shaped or rounded at bases, margins with very rounded teeth; dark green above, paler below, round petioles.

At 6 months leaves have assumed typical mature shape. X ½

Stem and buds at 1 year. Cross section angular. Lateral buds small and lanceolate. X 2

Cucumbertree
Magnolia acuminata L.
Family *Magnoliaceae*

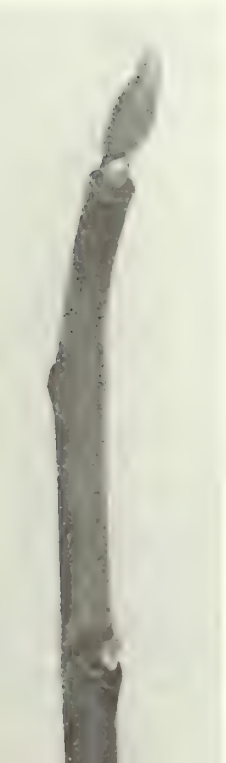
Leaf development and cotyledons on 2-week-old seedling. Inset shows stem emerging before cotyledons appear. X 2

Seedling at 4 months. X ½

Leaves.—First true leaves appear within 2 weeks after germination. Simple; alternate; bunched near stem terminal; deciduous, unlike those of southern magnolia. Ovate to oblong-obovate with short-pointed to acuminate apexes and rounded to wedge-shaped bases; margin entire and undulate on plane surface; medium green above, paler below; smooth on both surfaces; 4 inches long by 2 inches wide in 6 months.

Stem.—Emerges from ground in U-shape; easily and rapidly frees cotyledons from soil. Stout; round, and smooth; red on appearance, changing to purple, then olive green or gray by year's end; marked with a few small white lenticels and horseshoe-shaped leaf scars whose ends are connected by narrow stipule scars extending around stem.

Buds.—Terminal: ellipsoid with acuminate but blunt-pointed apex, light green and densely covered with silky, white hairs; about ⅜ inch long and ⅛ inch wide. Axillary: ovoid compressed; light green; moderately pubescent with soft white hairs especially near apex; about ⅛ inch long and nearly surrounded by narrow leaf scar.



Typical magnolia leaves are medium green, undulate on the plane surface, and deciduous. Terminal buds are large and heavily coated with white, silky hairs.

Cotyledons.—Elliptical to oval with rounded to blunt pointed apexes and rounded to slightly heart-shaped bases; moderate green and smooth on both surfaces; venation prominent. On appearance single cotyledons ½ inch long by ⅜ inch wide but more than double their size in first month. Persist on stem for almost 6 months after germination.

Stem at 1 year. Note relative size and arrangement of buds. X 2

Devils-Walkingstick
Aralia spinosa L.
Family *Araliaceae*

Compound leaves, frequently with spines, are clustered near the terminus of a spiny stem.

Cotyledons.—Oval with rounded apex and base; dark green and smooth on both surfaces; ¼ inch long by ⅛ inch wide. Persist on plant through first 3 months.

Leaves.—First true leaves appear 5 days after germination. First pair opposite, later ones alternate; pinnately compound with three to five leaflets. By end of first year some leaves doubly compound; pinnae with two to three pairs of leaflets and terminal leaflet. Leaflets ovate with acuminate apex and rounded base; margin finely serrate; medium green above, lighter gray-green below. Upper surface with quite a few fine spines, sparser below and mainly along midrib and main lateral veins. Leaf petioles light purple and with a few prickles; swollen at base.

Stem.—Reddish-violet for first few weeks, changing to brown on more mature portions by 3 months; smooth and circular. Leaf scars conspicuous, narrow and nearly encircle stem.

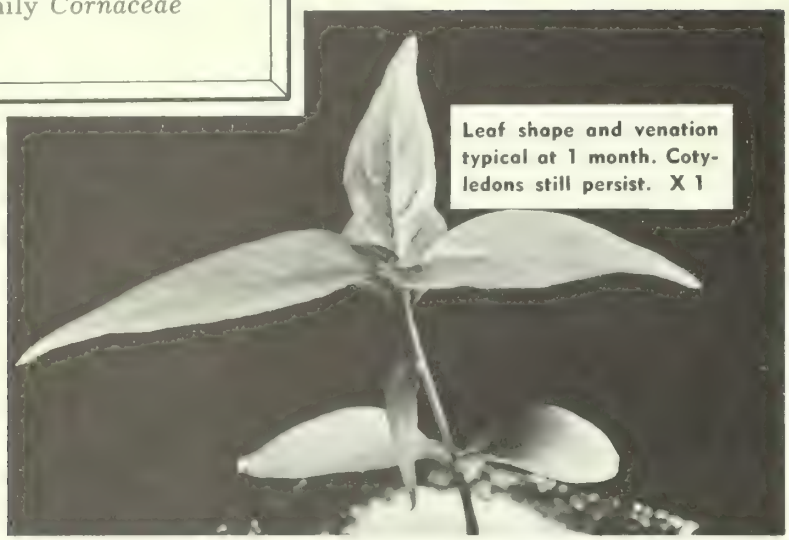
Buds.—Chestnut brown and smooth; terminal ones cone-shaped with blunt apexes, 3/16 to 3/8 inch long; axillary buds triangular and flattened, smaller than terminal ones.

Cotyledons 2 days after germination. X 3

Leaf detail at 11 weeks. Note spines on upper surface. X 2/3

Stem and terminal bud at 1 year. Note prominent leaf scars bunched at end of stem. X 4

Flowering Dogwood
Cornus florida L.
Family *Cornaceae*



Leaf shape and venation typical at 1 month. Cotyledons still persist. X 1

Stems are red when young. Typical dogwood leaf venation shows lateral veins curving upward toward the leaf tip. Red coloration is occasionally seen along veins about a month after germination.

Cotyledons.—Ovate with bluntly rounded apex and slightly wedge-shaped base; medium green on upper surface, a little lighter below. Venation much like that of mature foliage. Size more than doubles in first month, growing from spread of ¾ of an inch to 2 inches.

Leaves.—First true leaves appear about 4 days after germination; before unfolding resemble pine needles (see cotyledon photo) but are much more delicate. When unfolded, simple, opposite, ovate to elliptic, often narrowed to slender point at apex and with wedge-shaped base; light to medium green above, pale gray-green below; margin entire; smooth on both surfaces; and with prominent midrib and parallel lateral veins curving toward leaf tip.

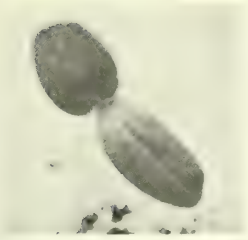
Stem.—Circular; red at first, becoming bright green when actively growing, later turning reddish-brown, especially near base; slightly hairy. Nearly encircled by narrow ring-like leaf scars.

Buds.—Ovoid, acute; light green; slightly hairy; about 3/16 inch long. Terminal buds with two valvate scales, and slightly longer than axillary buds.

Cotyledons and first leaves 4 days after germination. X 2

Stem, buds, and leaves at 1 year. X 2

Roughleaf Dogwood
Cornus drummondii C. A. Meyer
Family *Cornaceae*



Cotyledons 3 days after germination. X 2

Opposite leaves with typical dogwood venation and rough upper surface develop within the first 6 months.

Cotyledons.—Elliptic to oblong with bluntly rounded apex and base; midrib and lateral veins noticeable; medium green and smooth on both upper and lower surface; single cotyledon ¾ inch long and ⅜ inch wide.

Leaves.—First leaves appear within a week after germination; simple, opposite; ovate to ovate-lanceolate with acute to acuminate apexes and usually rounded bases; margins entire. Upper surface olive to medium green and roughened by short white hairs within a month, paler below with some pubescence; conspicuous veins run parallel to leaf margin.

Stem.—Round; light green and slightly hairy when they appear, usually turning pale red to red-brown toward end of first year; remaining slightly hairy.

Buds.—All buds reddish-brown and covered with whitish hairs. Terminal buds lanceolate with sharp point, 3/16 inch long; axillary buds ovoid and blunt, about 1/16 inch long.

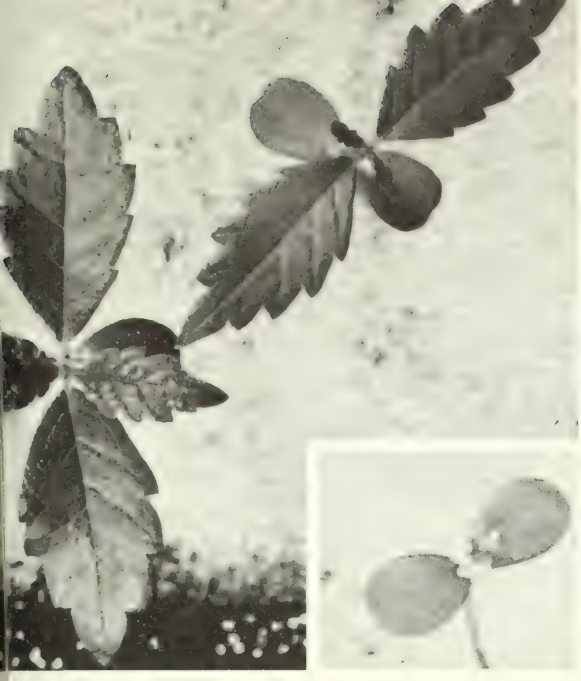
Stem and buds hairy, reddish-brown at 1 year. X 4

Seedling at 1 month. Note rough upper surface of leaves due to short white hairs. X 2

Table 2.—*Comparison of first-year elm seedlings*

Species	Leaves				Stem		Bud pubescence	Remarks
	Arrangement	Size and shape	Pubescence	Texture	Pubescence	Corky wings		
American elm	Opposite	2 to 4 inches long. Short pointed apex	None, to downy below	Rough upper surface	Moderate and soft at first. Rough to touch after a few weeks	None	None	
Cedar elm	Alternate	1 to 2 inches long. Rounded apex	None	Very rough upper surface	Moderately dense, stiff, white hairs, rough to touch	Few intermittent patches on main stem	Slight	
September elm	Opposite on main stem. Alternate on lateral branches	3 inches long. Acuminate apex	None at first. Fine down above after 6 months	Sometimes slightly rough above	Light on young stems	Heavy, in three ranks on lower portion of stem	None	
Slippery elm	Opposite but occasionally alternate	4 inches long. Acuminate apex	Slight amount below	Rough upper surface	Moderately dense rough red or white hairs	None	Moderately dense rusty hairs	
Waterelm (Planertree)	Alternate	2 to 4 inches long. Acute apex	None	Rough upper surface	Very light	None	Slight	Buds dark reddish-brown, other species chestnut brown
Winged elm	Alternate	1½ to 3 inches long. Acute to acuminate apex	None	Both surfaces smooth	Light	Small amounts, two ranks on stem	Slight	Stems sometimes zigzag, especially near terminal. Cotyledons with slightly notched apexes. Buds slender and sharp-pointed

American Elm
Ulmus americana L.
Family *Ulmaceae*



Seedlings at 2 weeks. Inset shows cotyledons 1 week after germination. X 2

Stem and buds at 1 year. X 2

Leaves and buds are opposite on first-year stems. Primary venation is parallel from midrib to leaf serration points. Leaf surface and stems are rough.

Cotyledons.—Medium green, broadly oval and smooth on both surfaces, ¼ inch long by 3/16 inch wide. More nearly round at apexes than those of other elms, but comparisons are necessary to make distinction clear. Persist on seedlings for several months after germination.

Leaves.—First leaves appear on elongating stem within 2 weeks after germination. Simple; oblong-elliptic, narrowing abruptly at apexes to long sharp points; bases symmetrical and wedge-shaped; margins coarsely serrate; parallel primary veins extend from midrib to points of teeth. Dark green; leaf surface rough above, smooth to downy below. Opposite in first season, alternate thereafter and on sprouts growing from broken or severed first-year stems. Alternate the first year in other elm species, except September elm, and occasionally slippery elm.

Stems.—At first light green and coated with soft pale hairs, gradually changing to reddish-brown and marked by scattered pale lenticels. After the first few weeks become rough to the touch. Round in cross section throughout.

Buds.—Ovoid, pointed and slightly flattened, ⅛ inch or less in length with ovate chestnut brown smooth scales. Arrangement on stem like that of leaves: opposite during first year, later becoming alternate. On 1-year twigs, upper set of laterals and terminal form bud cluster like those of oaks, but smaller. Leaf scars below buds are prominent, elevated, semicircular, and show ends of three large fibrovascular bundles.

Leaf arrangement opposite at 2 months. X ½

Cedar Elm
Ulmus crassifolia Nutt.
Family *Ulmaceae*

Stem and buds at 1 year. X 2

Small, typical elm leaves are alternate and have rounded tips. Upper surface is rough. Small corky wings develop on stem late in the first year.

Cotyledons.—On appearance dark green; smooth; roughly rectangular with decidedly truncate apexes; 3/16 inch long by ⅛ inch wide. Grow little if any after appearance and are shed during first half year.

Leaves.—Simple; alternate; ovate with apexes rounded or sometimes acute and bases rounded to slightly heart-shaped; margin coarsely, doubly serrate; dark green and lustrous above, paler below; small stipules present. Upper surface thickly covered with minute sharp-pointed tubercles that produce roug texture. Lower surface smooth or with spars white pubescence. Prominent parallel venatio below, extending in straight lines from midri to margin. This species, water elm, and winge elm only ones with alternate leaves, buds, an twigs at first appearance.

Stem.—Round; at first olive green to ligh brown, appearing slightly striped and covere with moderately dense coating of short, stif white hairs that produce rough texture. B midyear changing to red-brown and becomin smooth; marked with very few, small, incon spicuous, round, white lenticels. A few sca tered, intermittent patches of corky wings o stem and lateral twigs; wing development mo extended after first year.

Buds.—Ovoid and blunt; chestnut-brow slightly hairy; ⅛ inch or less in length. Term inal bud lacking.

Seedling at 2½ months. Upper surface of leaves rough. X 1

Corky wings on stem at 8 months (just below both lateral branches). X 1

Cotyledons at 5 days. X 2

September Elm
Ulmus serotina Sarg.
Family *Ulmaceae*

Basal portion of 6-month-old stems. Note three-ranked corky wings and first lateral branch (center) with alternate leaves. X ½

Corky wings develop abundantly in three ranks around the main stem by midseason of the first year.

Cotyledons.—Oval with definitely truncated apexes and rounded bases; medium green and smooth on both upper and lower surface; single cotyledon ¼ inch long and 3/16 inch wide on appearance. Grow little, if any, but persist on plant for about 3 months after germination.

Leaves.—First leaves appear by close of first week. Simple; opposite; oblong to ovate with acute to acuminate apexes and rounded bases; margins coarsely and doubly serrate; medium green above, paler below; at first smooth on both surfaces but after 6 months very finely pubescent above and starting to develop rough upper surface. About 3 inches long by 1½ inches wide 2 months after germination. First lateral branches opposite, developing in latter half of first year in leaf axils along main stem, but leaves forming on them arranged alternately.

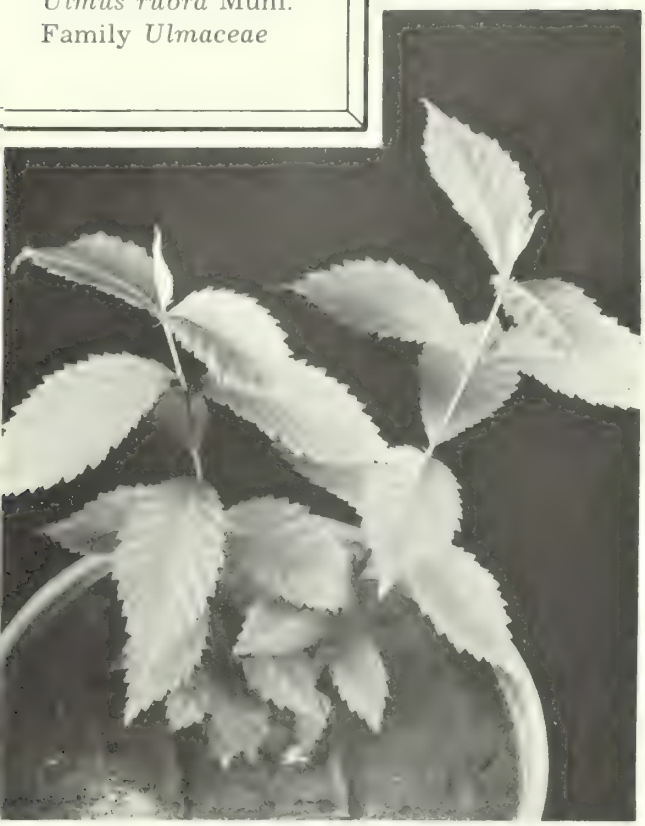
Stem.—Circular; at first green, turning to brown with maturity; lightly pubescent on younger portions. Usually, three ranks of light tan corky wings develop on lower portions of stems after 6 months. These wings more abundant and continuous along stem than on other species where they develop.

Buds.—Terminal ones lacking, axillaries ellipsoid with acute apexes; smooth; chestnut brown; ⅛ inch long at end of first year.

Stem and buds at end of first growing season. X 2

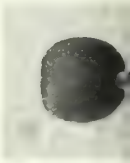
Cotyledons after 2 weeks. X 2

Slippery Elm
Ulmus rubra Muhl.
Family *Ulmaceae*



Four-month-old seedlings. Plant at left illustrates occasional alternate arrangement of leaves during the first year. X 3/10

At 3 weeks leaf margins more coarsely serrate than on older plants. X 2



Cotyledons 3 days after germination. X 2

Leaves show characteristic elm form and venation but have rough, sandpapery upper surfaces and long tapering apexes.

Cotyledons.—Oval with truncated apexes and round to slightly heart-shaped bases; medium to dark green on both surfaces; at first slightly pubescent with short white hairs around margin and on upper surface; smooth below; becoming smooth on both surfaces after about a month.

Leaves.—First true leaves appear within 3 days after germination. Simple; principally opposite, occasionally alternate; ovate to oblong-ovate with acuminate apexes and round to wedge-shaped bases; margins coarse and doubly serrate; dark green; smooth above and slightly pubescent below along veins and margin for first month; later, short tubercles pointing toward apex develop on upper surface producing characteristic rough texture of leaves; soft hairy below. About 1 inch long and 5/8 inch wide 1 month after germination; longer and broader than those of winged elm.

Terminal portion of stem at 1 year. Note typical leaf scar and stem pubescence. X 4

Stem.—Light red and moderately hairy on appearance, changing to green in a few weeks while remaining coated with short red or white hairs; turning brown and marked with considerable number of small, white lenticels and elevated nearly round leaf scars by close of first year. Round throughout length and roughly hairy.

Buds.—Broadly ovoid and blunt-pointed; dark chestnut-brown; moderately pubescent with rusty hairs; ⅛ to ¼ inch long. Terminal buds lacking.

Winged Elm
Ulmus alata Michx.
Family *Ulmaceae*

Cotyledons 2 days after germination. X 2

Stem light reddish-brown at 1 year and growth zigzag. Lenticels white to orange. X 2

Typical leaf size, shape, and serration at 1 month. X 1

Small, sharp pointed leaves have typical elm venation. Corky wings form on stem near end of the first year. This tree is not found on wet sites.

Cotyledons.—Oval; apexes shallowly notched and bases heart-shaped; light green and smooth on both surfaces; persist on plant for 1 to 2 months.

Leaves.—First leaves appear within 1 week after germination. Simple; first pair opposite, subsequent ones alternate; ovate to oblong-lanceolate with acute to acuminate apexes and rounded to wedge-shaped bases; margins coarsely and doubly serrate; dark green above, slightly paler below; smooth on both surfaces. Small stipules present. Pointed leaves help distinguish seedlings of this species from cedar elm.

Stem.—Circular; zigzag, especially at end of stem; slightly hairy to smooth; at first light to olive green, becoming light reddish-brown in latter portion of first year; marked with a few small white to orange lenticels. Two corky wings begin to develop opposite each other on stem late in first year.

Buds.—Slender and sharp-pointed; chestnut brown; slightly hairy; 1/16 inch long. No terminal buds.

Hackberry
Celtis occidentalis L.
Family *Ulmaceae*

Leaf shape a
week. X 1½

Notched cotyledons identify the genus but not the species. Like sugarberry, the young seedlings have a flat, spray-like appearance, resulting from alternate twig arrangement in the same plane.

Cotyledons.—Elliptical with deeply notched apex and round to truncated base; light green and smooth on both surfaces. Single cotyledons about 5/8 inch long and 3/8 inch wide upon emergence and grow very little. Persist on plant for 3 months.

Leaves.—First leaves appear during first week after germination and plant grows rapidly. Simple, alternate after first pair, which is opposite; ovate to ovate-lanceolate with acute to short-acuminate apexes and rounded to truncate bases; margins coarsely serrate; upper surface dark green with moderate coating of short, stiff hairs or tubercles that produce rough texture; lower surface a little lighter green than upper and smooth; 2 to 3 inches long at 6 months.

Stem.—Circular throughout; green at first, changing to reddish or dark brown in latter half of first year, marked with moderate number of small, round to oblong, white lenticels; slightly pubescent with short white hairs. Growth zigzag; early leaves and lateral branches develop in single plane, producing typical spray-like appearance.

Buds.—Ovoid, blunt pointed; chestnut brown; sparsely pubescent; 1/16 inch long. Terminal buds lacking.

Stem and buds at 1
year. X 2

Cotyledons 3 days after germination. X 2

At 6 months mature leaf traits and spray-like form of young plants help to identify species. X 1/4

Hawthorn
Crataegus L.
Family *Rosaceae*

At 1 month lobing starts. X 3. Inset shows cotyledons and first leaf at 1 week. X 2

Stem at 1 year bears spines. X 1½

Note: The species of plant described below was not definitely established but appears likely to have been littlehip hawthorn, *C. spathulata* Michx. It is used to illustrate seedling development for the difficult-to-separate species of this genus.

Hawthorn general: small leaves variously toothed, lobed, and notched; stems with long slender spines at nodes. Species illustrated: ovate leaves, three- to five-lobed at apex, tapering to winged petioles with large, foliaceous, serrate stipules at their base.

Cotyledons.—Oval with rounded apexes and rounded to truncate bases; medium green and smooth on upper surface; single cotyledon ⅜ inch long by 3/16 inch wide after 1 week. Persist on plant for about 1 month.

Leaves.—First leaves appear within week after germination. Simple; alternate; ovate, mostly three- to five-lobed at apex; finely serrate on margin, wedge-shaped base entire and tapering to winged petiole; apexes acute; dark green and smooth above, gray-green below with a few hairs along veins; 2½ to 3 inches long by 1 inch wide. Foliaceous stipules with serrate margins at base of leaves.

Stem.—Circular; greenish to red-brown; smooth; marked with a few round white lenticels. Growth slightly zigzag. Usually armed at nodes with slender, sharp, smooth, brown spines ½ inch or more in length.

Buds.—Globular; smooth; dark red-brown; 1/16 inch or less in diameter and occurring beside spines when stem is armed.

Seedling late in first year. X ½

Table 3.—*Comparison of first-year hickory seedlings*

Species	Leaves				Stem		Buds			Remarks
	Type	Pubescence	Color	Leaflet size and shape	Pubescence	Color	Shape	Pubescence	Color	
Bitternut	Compound. Three leaflets at first, later five.	At first heavy on both surfaces, later smooth	Tinged with red as they unfold, later moderate to light green on upper surface. Paler below.	Ovate-lanceolate. 3" long × 1½" wide at 6 mos.	Smooth	Red first month, then changing to brown with green stripes	Slender, pointed	Dense scurf	Bright yellow	Bud scales valvate
Mockernut	Compound. Three leaflets. Sometimes has simple leaves.	Smooth on both surfaces	Medium green on upper surface. Paler below.	Ovate to ovate-lanceolate. Terminal: 3-4" long × 2½" wide. Lateral: 1½" long × ¾" wide at 3 mos.	Smooth	Light brown	Broad ovoid	Smooth	Light brown	Leaflet margins coarse serrate. Leaves fragrant when crushed. Stipules prominent.
Nutmeg	Compound. Three leaflets.	Smooth, except for some hairs along midrib on lower surface	Medium green on upper surface. Paler below.	Terminal: ovate to elliptical, long tapering base, 1½" long × 1" wide. Lateral: elliptical. 1" long × ⅝" wide at 2 mos.	Covered with golden to brown scurfy scales	Light red on appearance, becoming brown in a few mos.	Terminal: long ovoid. Lateral: similar but smaller.	Thick scurf	Brown	Bud scales valvate
Pecan (sweet)	Simple until late in first year	Sometimes hairy below	Dark yellow-green above	Lanceolate. 3-4" long × ¾" wide at 2 mos.	Coated with pale hairs at first, changing to slightly hairy near terminal	At first slightly red, later reddish-brown	Ovoid, slightly compressed	Covered with light, jointed hairs	Red-brown	Typical compound leaves appear late in first year
Pignut	Compound. Three leaflets. Sometimes has simple leaves.	Smooth on both surfaces	Dark to medium green above. Paler below.	Terminal: ovate, 4-5" long × 1¾" wide. Lateral: lanceolate-ovate, 1½" long × ½" wide at 6 mos.	Hairy at first, becoming smooth by midyear	First weeks reddish to red-brown, later dark brown	Ovoid	Smooth	Light brown	
Water	Simple until late in first year	Sometimes hairy below	Red on unfolding, medium green on upper	Lanceolate-ovate. 3-4" long × ¾" wide at 6 mos.	Covered with pale hairs at first, becoming smooth	Dark reddish-brown to gray	Ovoid, flattened; slight point	Slight	Dark red-brown	Typical compound leaves appear late in first year

Bitternut Hickory
Carya cordiformis
(Wangenh.) K. Koch
Family *Juglandaceae*

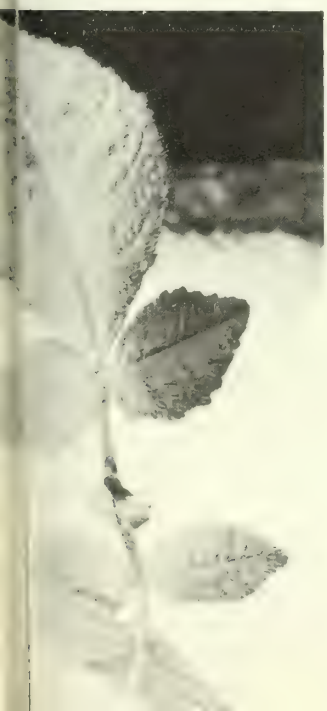
Stem and buds at 1 year. X 2

This species generally has smaller leaflets than other hickory species. The terminal bud is bright yellow.

Cotyledons.—Do not appear above ground.

Leaves.—First leaves are opposite pair, odd-pinnately compound with three leaflets, terminal one large. Later leaves alternate and may have as many as five leaflets. Leaflets ovate to ovate-lanceolate and sessile or nearly so, terminal leaflets slightly petioled, acute to acuminate at apex and with wedge-shaped bases; margins finely serrate; tinged with red as they unfold and heavily pubescent with short white hairs above and below, becoming moderate to light green above, slightly paler below and smooth on both surfaces after a few weeks. Terminal and larger lateral leaflets 2½ to 3 inches long by midyear, generally smaller than those of most other species of hickory.

Leaves at 6 months. X 1



Leaves at 2 weeks. X 2

Stem.—Round throughout; smooth; red for first month, changing to light brown striped with green by midyear; few small white lenticels.

Buds.—Slender and bright yellow with valvate scales; scurfy pubescent; terminal: ¼ to ½ inch long, oblique at apex; axillary: two-angled, often stalked; ⅛ to 3 16 inch long.

Mockernut Hickory
Carya tomentosa Nutt.
Family *Juglandaceae*

Stipules persist at 1 year. X 2

At 3 weeks plant sometimes has a simple leaflet. X ½

Large, plump terminal buds are among the largest of those of hickories. Leaves have a resinous fragrance when crushed.

Cotyledons.—Do not appear above ground.

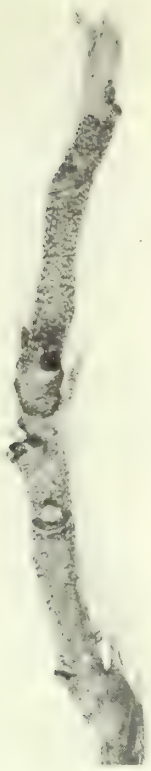
Leaves.—Alternate; odd-pinnately compound with three leaflets, single leaflets sometimes occur on plants in first year. Leaflets ovate to ovate-lanceolate with acute to acuminate apexes and wedge-shaped to rounded bases; lateral leaflets sessile or nearly so, terminal ones with short petiole. Margins coarsely serrate; medium green above and paler below; smooth on both surfaces; prominent stipules. Terminal leaflets 3 to 4 inches long and 2½ inches wide, laterals about 1½ inches long and ¾ inch wide 3 months after germination.

Stem.—Round; light brown; smooth and marked with conspicuous pale lenticels.

Buds.—Broadly ovoid, acute to blunt-pointed; light brown; smooth; terminal: ¼ inch long; axillary: 1/16 inch long.

Leaf shape and size after 3 months. X 3/4

Nutmeg Hickory
Carya myristicaeformis (Michx. f.) Nutt.
Family *Juglandaceae*



Terminal portion of 1-year-old stem. Note scaly appearance and minute axillary buds. X 4

Leaf arrangement at 2 months. X 1

Midrib on the lower surface is hairy. The small brown buds are scurfy pubescent with valvate scales.

Cotyledons.—Do not appear above ground.

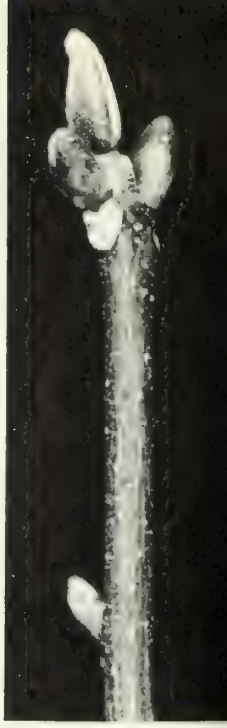
Leaves.—Alternate; compound, having three leaflets; terminal leaflets ovate to broadly elliptical with long tapering base and apex, petiole short, lateral leaflets elliptical with obtuse apexes and rounded bases, nearly sessile; margins finely serrate; medium green and smooth on both surfaces except for some pubescence along midrib below. Terminal leaflets 1½ inches long and ¾ to 1 inch wide; lateral ones 1 inch long and ½ to ⅝ inch wide 2 months after germination.

Stem.—Pink to light red on appearance, becoming brown by end of first year; round; coated with golden to brown scales.

Buds.—Covered with thick brown scurfy pubescence; bud scales valvate; terminal bud long ovoid with somewhat obtuse apex, ⅛ to ¼ inch long; axillary much smaller, acute and slightly blunted.

Seedling at 1 week. X 2

Pignut Hickory
Carya glabra (Mill.) Sweet
Family *Juglandaceae*



Terminal portion of stem at 1 year. Lenticels white. X 4

No particularly useful characteristics are observed. This species is difficult to distinguish from mockernut hickory.

Cotyledons.—Do not appear above ground.

Leaves.—Alternate; mostly odd-pinnately compound, terminal and two lateral leaflets, but simple leaves sometimes occur; terminal leaflets ovate, have short petiole and are 4 to 5 inches long and 1¾ inches wide at midyear; lateral leaflets lanceolate-ovate, sessile, and 1½ inches long by ½ inch wide at midyear. All leaflets have acuminate apexes and rounded or wedge-shaped bases; margins finely serrate; upper surface dark to medium green, lower surface a little paler; both surfaces smooth.

Stem.—Circular throughout; for first few weeks reddish to red-brown and slightly pubescent; becoming dark brown, smooth and marked with moderate number of small white lenticels.

Buds.—Ovoid with acute apexes; light brown; smooth; terminal ones ¼ inch long, axillary ones ⅛ inch long.

Seedling at 3 weeks after germination. Note two types of leaves and arrangement on stem. X 1

Leaf shape and size at midyear. X ½

Water Hickory
(frequently Bitter Pecan)
Carya aquatica (Michx. f.) Nutt.
Family *Juglandaceae*

Stem and buds at 1 year. Note elevated leaf scars and prominent lenticels. X 2

No outstanding characteristics separate this species from pecan *(Carya illinoensis)*, the only seedling hickory with which it is easily confused. Site is probably the best identification guide; water hickory frequents low, wet flats, while pecan is found only along riverfronts and on ridges elsewhere.

Cotyledons.—Do not appear above ground.

Leaves.—Alternate; simple; lanceolate-ovate with acute apexes, bases symmetrical and rounded or unsymmetrical and wedge-shaped; margins finely serrate. Red to maroon on appearance, changing to medium green after a few weeks; smooth and shiny above and sometimes hairy beneath. Typical odd-pinnately compound leaves of more mature plants do not develop until near end of first growing season or in second year.

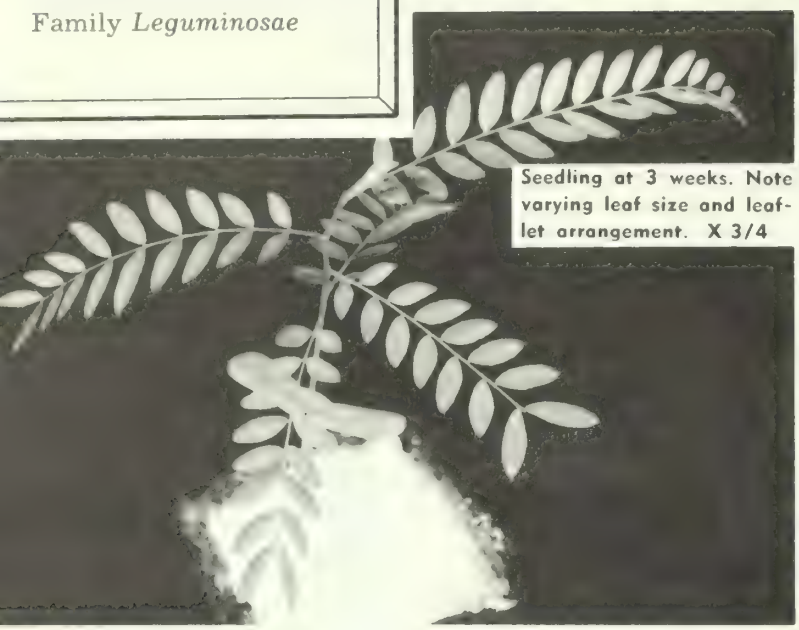
Stem extremity and terminal bud slightly hairy at 1 year. X 4

Seedling 3 weeks after germination. X1

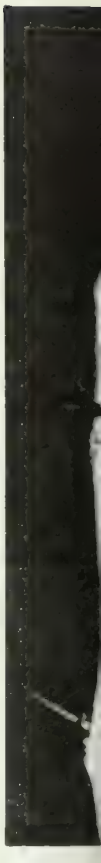
Stem.—Dark reddish-brown to gray, at first coated with loose pale woolly hairs, later smooth with numerous, small, white lenticels. Marked in winter by small, nearly oval or triangular, elevated leaf scars. Stem cross section round throughout.

Buds.—Winter buds slightly flattened and pointed; dark reddish-brown; terminal ⅛ to ¼ inch long, often hairy; lateral buds much smaller.

Honeylocust
Gleditsia triacanthos L.
Family *Leguminosae*



Seedling at 3 weeks. Note varying leaf size and leaflet arrangement. X 3/4



At 1 year stem is zigzag and light gray-green. X 2

with purple-brown, stout, rigid spines ¼ to ½ inch long; mainly three-pointed but sometimes simple. Distribution along stem fairly uniform as contrasted with bunching near base found on water locust.

Buds.—Red-brown; smooth; terminal bud lacking; axillary buds minute and inconspicuous.

Cotyledons and first leaf at 3 days. X 2

Small leaflets resemble those of mimosa. Abundant three-forked thorns are distributed uniformly along stem and are well developed by the latter half of the first year.

Cotyledons.—Oval with rounded apexes and slightly notched bases; light green and smooth on both surfaces; individual cotyledon ½ inch in length. Persist on stem for about a month.

Leaves.—First leaves appear within a few days after germination. Alternate; once pinnately compound during first year; 1 to 2½ inches long; leaflets 15 to 30 opposite or alternate on rachis; almost sessile; ½ inch long and 3/16 inch wide; oblong-lanceolate with rounded apexes and bases; margin with very small, rounded teeth to entire; medium green and lustrous above, paler below; both surfaces smooth.

Stem.—Red-brown at first, becoming light gray-green by end of first year; zigzag; circular; and with minute lenticels. Armed after midyear

Thorn development on 8-month-old locust seedlings. Evenly distributed along stem on honeylocust (left); larger and branched, with concentration near base on waterlocust (right). X 3/10

Eastern Hophornbeam
Ostrya virginiana (Mill.) K. Koch
Family *Betulaceae*

At 1 year stipules persist at nodes. X 2

Coarse, doubly serrate leaf margins have short bristles at serration tips. Venation is prominent and similar to that on elm leaves.

Cotyledons.—Elliptical with rounded apexes, slightly notched bases, and very short petioles; dark green above, gray-green below, and smooth on both surfaces. Single cotyledon 5/16 inch long and ⅛ inch wide on appearance and grows little before being shed about 2 months after germination.

Leaves.—First leaves appear during first week. Simple; alternate; ovate tapering to dull acute apex and rounded or slightly heart-shaped base; margin coarsely, partially doubly serrate with small bristles present at serration apexes. After a month, 1⅛ inches long by ⅝ inch wide; prominent, parallel venation similar to that of elm leaves; medium dull green above, paler below, and smooth on both surfaces.

Cotyledons still attached to stem at 1 month. Inset shows cotyledons as they appear. X 2

Leaf characteristics at 1 month. X 2

Stem.—Zigzag; round; red and smooth on appearance, changing to light brown or tan and finely pubescent after a few weeks. Long narrow stipules persist at leaf scars.

Buds.—Ovoid and pointed; light brown or tan and with some white hairs. Terminal buds largest, ⅛ inch long; axillary ones minute to ½ size of terminals.

American Hornbeam
Carpinus caroliniana Walt.
Family *Betulaceae*

Stem and buds at 1 year. X 2

First lateral branches developing at 5 months. X 1/4

Pear-shaped cotyledons have short petioles and pronounced V-notch at base. Leaves are coarsely, doubly toothed with sharp-pointed serrations, and venation, as on elm leaves.

Cotyledons.—On appearance, nearly round with small V-shaped notch at base and very short petiole; dark green and smooth on both surfaces; single cotyledons ⅛ inch long. Growing in a week to ⅜ inch long by 5/16 inch wide, becoming pear-shaped with notch and petiole more pronounced than at first. There is no further growth. Persist on stem for about 3 months.

Leaves.—First true leaves appear during first week after germination. Simple; alternate; ovate with acute to acuminate apexes and rounded to wedge-shaped or sometimes unequal bases; margin coarsely and doubly serrate, serration tips bearing short spines; medium green; smooth, and somewhat glossy on both surfaces; 2¼ inches long by 1 inch wide at 6 months after germination. Veins prominent on upper surface of leaf, parallel, and extending at acute angle from midrib to leaf margin, similar to those on elm.

Stem.—Zigzag; circular; smooth; light green on appearance, becoming dark red and shiny by end of first year; marked by many small white lenticels.

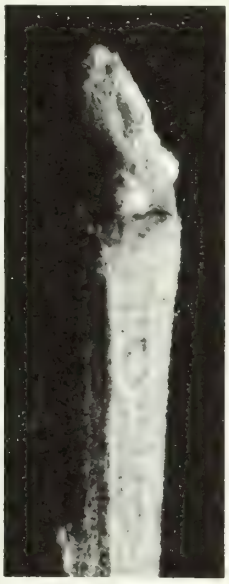
Buds.—Ovoid with short, sharp-pointed tip; red-brown; smooth; ⅛ inch long with terminal buds a little plumper than axillary ones.

Seedling at 1 month. Short petiole present on cotyledons. Note basal notching of cotyledons on appearance (inset). X 2

Poison-Ivy
Rhus radicans L. *(Toxicodendron radicans* (L.) Kuntze)
Family *Anacardiaceae*

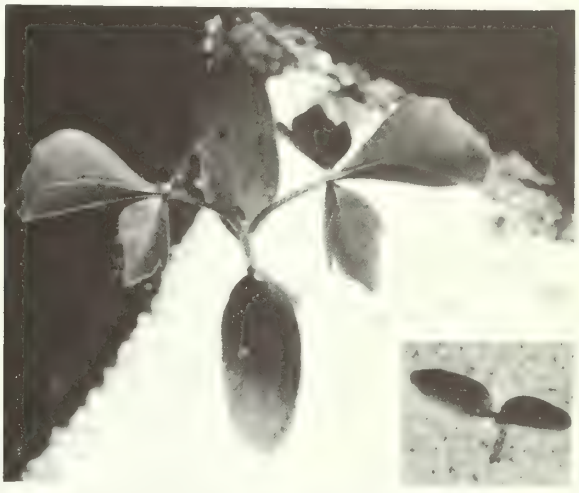
Compound leaves with three leaflets have entire to lobed mar-ns and are often shiny above. They exhibit characteristic poison-y foliage within a few weeks after germination.

Cotyledons.—Elliptical with rounded apexes and bases; medi-n green and smooth on both surfaces; single cotyledon ¼ inch ng by ⅛ inch wide on appearance; double in size within first nth. Persist on stem for about 6 weeks.



Terminal portion of 1-year-old stem including pubescent buds and typical leaf scar. X 4

Stem and buds at 1 year. X 2



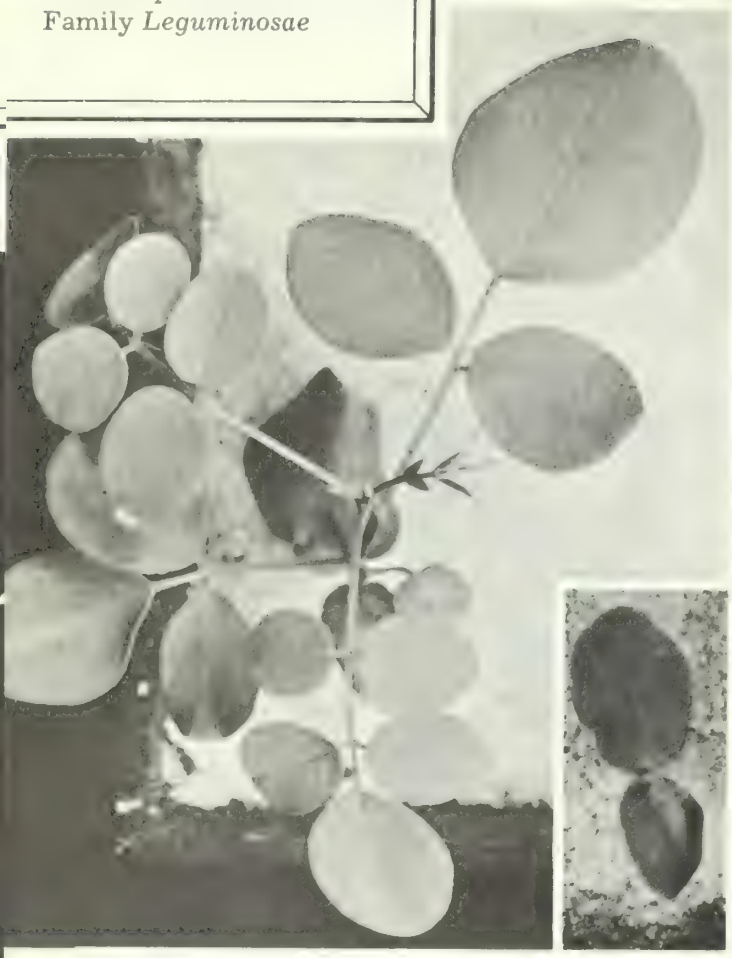
Typical seedling at 1 month. X 1½. Inset shows cotyledons at 2 days. X 2

Leaves.—Alternate; compound, trifoliate; leaflets lanceolate, ovate, or occasionally obovate, narrowing gradually to long blunt point at apex; and bases rounded to wedge-shaped; axillary leaflets sessile or nearly so. Margin entire or lobed, extremely variable; medium green, smooth and frequently shiny on upper surface, slightly paler and hairy below; leaflets ⅜ to ⅝ inch long by 3/16 to ⅜ inch wide at 1 month; terminal leaflets larger.

Stem.—Circular; brownish-gray, smooth to slightly pubescent; leaf scars V-shaped; usually erect during first year but may begin climbing on other vegetation or support toward end of season.

Buds.—Brownish and moderately pubescent; without scales; terminal buds ovoid with blunt pointed apex, ⅛ inch long; axillary buds flattened and triangular-shaped, 1/16 inch long.

Black Locust
Robinia pseudoacacia L.
Family *Leguminosae*



Leaf and leaflet details at 2 weeks. Note cotyledons at appearance (inset). X 2

One-year stems are zigzag and bear thorns at nodes. X 2

Leaves are pinnately compound; leaflets are slightly larger than those of honeylocust or waterlocust. Stem is armed with short, straight, sharp thorns usually borne in pairs at the nodes.

Cotyledons.—Oval to ovate with rounded apex and base; medium green above, paler below; smooth on both surfaces; ½ inch long by ⅜ inch wide on appearance; grow little.

Leaves.—First leaf appears within a week after germination. Alternate; odd-pinnately compound; 3 to 4 inches long after 2 months. Leaflets 3 to 15, opposite or alternate on rachis; nearly sessile; ½ to 1 inch long by ⅜ to ¾ inch wide, terminal leaflets frequently a little larger; oval to ovate-oblong with rounded base and apex; margin entire; dark green; when they unfold covered with white hairs that are shed early; later smooth on both surfaces.

Leaves are 3 to 4 inches long at 2 months. X ½

Stem.—Zigzag; round to slightly angular in cross section; smooth; dark olive green to reddish-brown and with many small pale lenticels. Pairs of thorns develop from stipules at base of leaf petiole, becoming noticeable in latter half of first year. Unbranched spines straight to curved; sharp; attain length of ⅛ to ¼ inch in first year.

Buds.—Terminal buds lacking; axillary buds minute; spherical; light tan and covered with sparse white pubescence; partially submerged in leaf scar.

Southern Magnolia
Magnolia grandiflora L.
Family *Magnoliaceae*

Terminal bud at 1 year. Note typical pubescence of bud and upper stem. X 2

Evergreen leaves are large, shiny, and leathery. The large greenish, conical terminal bud is covered with rusty hairs.

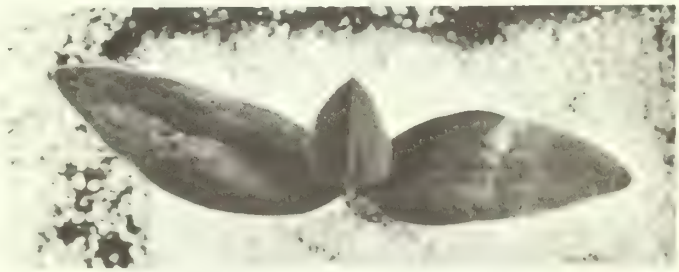
Cotyledons.—Lanceolate to elliptical, tapering toward bluntly rounded apex; shiny medium green and smooth on both surfaces; single cotyledon ½ inch long and ¼ inch wide on appearance and growing little. Persist on stem for approximately 2 months.

Leaves.—First true leaves appear within a week after germination. Simple; alternate; evergreen and leathery; variable in shape but most often elliptic or oval with short blunt-pointed or acuminate apexes and wedge-shaped bases; margin entire. Dark green, shiny, and smooth above, paler below and usually with light coating of rusty hairs especially along veins; 4¾ inches long and 1½ inches wide at 3 months after germination.

Stem.—Breaks through ground surface in U-shape, and cotyledons follow in a day or two. Circular; olive green; with moderate coating of short red hairs for first few months, then becoming smooth except on new growth.

Buds.—Terminal: conical and sharp-pointed; light green and heavily covered with tan pubescence; ¾ inch long. Axillary: ovoid; green; and with covering of short white hairs, particularly near apex; ⅛ inch long.

At 3 months foliage shiny, clustering on upper portion of stem. X ½



First leaf developing at 1 week. X 2

Red Maple
Acer rubrum L.
Family *Aceraceae*

Cotyledons and first leaves 4 days after germination. X 2

Leaves are opposite and usually three-lobed; the middle lobe often is longer than the others. Dark red, shiny twigs have round red buds.

Cotyledons.—No special characteristics distinguish cotyledons from those of other maples, except that length is normally half that of boxelder, the other species prevalent in bottom lands. Cotyledons elliptical with blunt, rounded apexes, smooth, medium green, and ½ inch long by ⅛ inch wide. Persist on plant for several weeks.

Leaves.—First true leaves appear within a day or 2 after cotyledons and are three-lobed, a characteristic accentuated in succeeding weeks. Simple; opposite; ovate to oval; truncate, slightly heart- or even wedge-shaped at base; apex long, narrow, blunt; margin coarsely serrate with V-shaped sinuses between lobes. Bright green and smooth on upper surface, lighter, even to white, and pubescent below, especially when unfolding. Within 2 weeks 1 inch long by ⅝ inch wide at broadest portion, and leathery.

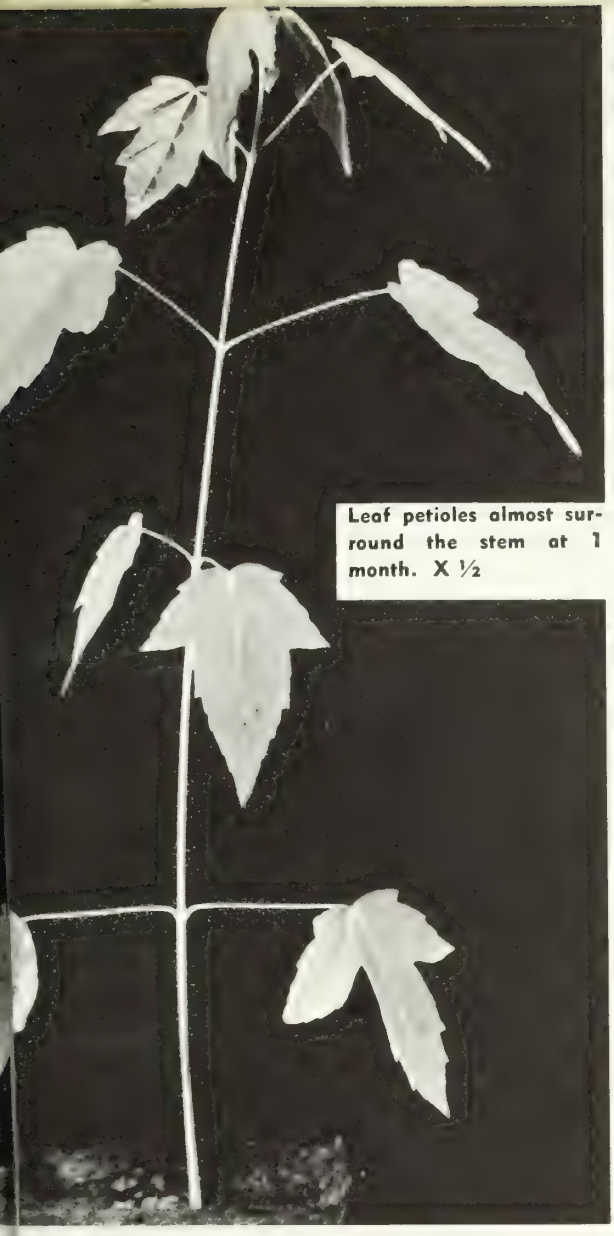
Stem.—Young stems green or dark red during first few months, becoming dark or bright red and shiny above, shading into red-brown near base at close of first summer; smooth and marked by whitish longitudinal lenticels. Stem cross section round throughout.

Buds.—Opposite on stem, round to obtuse with dark red outer scales ciliate on margins, and inner scales rounded at apex and bright scarlet. Lateral buds up to ⅛ inch long and terminal buds up to ¼ inch long.

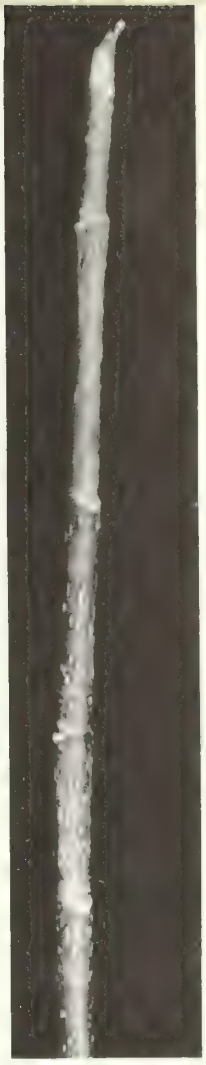
Seedlings 5 months after germination; leaf shape is typical. X ½

Stem and buds at 1 year; lenticels are white and lateral buds have an opposite arrangement. X 2

Silver Maple
Acer saccharinum L.
Family *Aceraceae*



Leaf petioles almost surround the stem at 1 month. X ½



Stem and buds at 1 year. Note rings formed by leaf scars. X 2

Leaf development 4 days after germination. No cotyledons are showing. X 2

Leaves are opposite and deeply cut into five lobes; the middle lobe itself often is three-lobed. Under surface is silvery white.

Cotyledons.—Do not appear above ground. This feature helps to distinguish the species from other maples commonly found in bottom lands.

Leaves.—Simple; opposite; truncate or heart-shaped at base with sharp-pointed apex. Five-lobed with V-shaped or rounded sinuses between lobes, margin coarsely serrate, upper surface pale green, lower surface silvery white and at first slightly hairy below, especially in axils of primary veins; petioles slender and red. Leaves begin to develop characteristic five-lobed form as early as 2 weeks after appearance, although pair of lobes nearest petiole remains indistinct for several additional weeks. Middle lobe clearly shows three-lobed form by this time.

Stem.—Light green at first, later becoming light chestnut brown, smooth and lustrous, covered with white lenticels. Narrow, opposite leaf scars almost meet around stem, forming noticeable lines. Round in cross section throughout.

Buds.—Opposite, ovoid with flattened point at apex; bright red outer scales ciliate on margins, 1/16 to ⅛ inch long; terminal buds largest.

Trident Red Maple
Acer rubrum L. (var. *tridens* Wood)
Family *Aceraceae*

Stem and buds at 1 year. Note numerous lenticels, development of first lateral branch, and typical terminal bud. X 4

Leaves are smaller than those of typical red maple, have rounded bases, and are usually three-lobed near the apical end. Buds are triangular and have blunted points.

Cotyledons.—Narrowly elliptic with rounded apexes and wedge-shaped bases; dark green; smooth. Single cotyledon ½ inch long by 3/16 inch wide on appearance and makes little growth.

Leaves.—Simple; opposite; ovate and three-lobed near apical end with acute to acuminate apexes and rounded or sometimes slightly heart-shaped bases; margin coarsely serrate to occasionally undulate below lobes; dark green and smooth on upper surface, glaucous with white hairs below; 2¼ inches long by 1½ inches wide at 3 months.

Stem.—Round; smooth; red on appearance, becoming red-brown by close of first year except rapidly growing portion, which is green; marked with many conspicuous, small white lenticels.

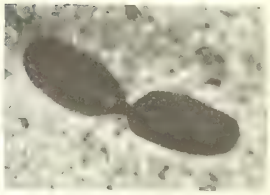
Buds.—Reddish and smooth; ⅛ inch long. Terminal: conical, dull pointed; axillary: compressed, conical, rounded at apex.

Typical trilobed leaves at 3 months. X ½

Cotyledons (left) second day after germination; first leaves (right) after 1 week. X 2

Red Mulberry
Morus rubra L.
Family *Moraceae*

Seedlings at 1 month. Note typical leaf shape and upper surface appearance. X 2



Cotyledons on appearance. X 4

Stem and buds at 1 year. Zigzag growth due to lack of terminal bud. Rough leaf scars characteristic. X 4

Sap is milky. Leaves vary in shape from ovate to mitten-like and often have three or more lobes. Veins prominent on underside.

Cotyledons.—Oval with rounded apex and rounded to slightly wedge-shaped base; medium green and smooth on both surfaces; single cotyledon about ¼ inch long on appearance, makes little growth. Persist on stem for 1 month.

Leaves.—First leaves appear within 2 weeks after germination. Simple; first pair opposite, later ones alternate; ovate to oblong-ovate with acute, dull-pointed apexes and deeply heart-shaped to occasionally truncate bases; unlobed for first 3 months, after which mitten-shaped and three-lobed leaves may be found on some seedlings; margin coarsely serrate; medium green and smooth underneath, but rather rough above, smooth textured and with prominent veins below; 1 to 1½ inches long by ¾ inch wide after 1 month. Milky sap exudes when leaf petioles are crushed or broken.

Stem.—Slightly zigzag; round; smooth; marked by considerable number of elliptic to oval, white to light tan lenticels; light green on appearance, later reddish-brown near base and gray on rest of stem. Breaking bark also results in exudation of milky sap.

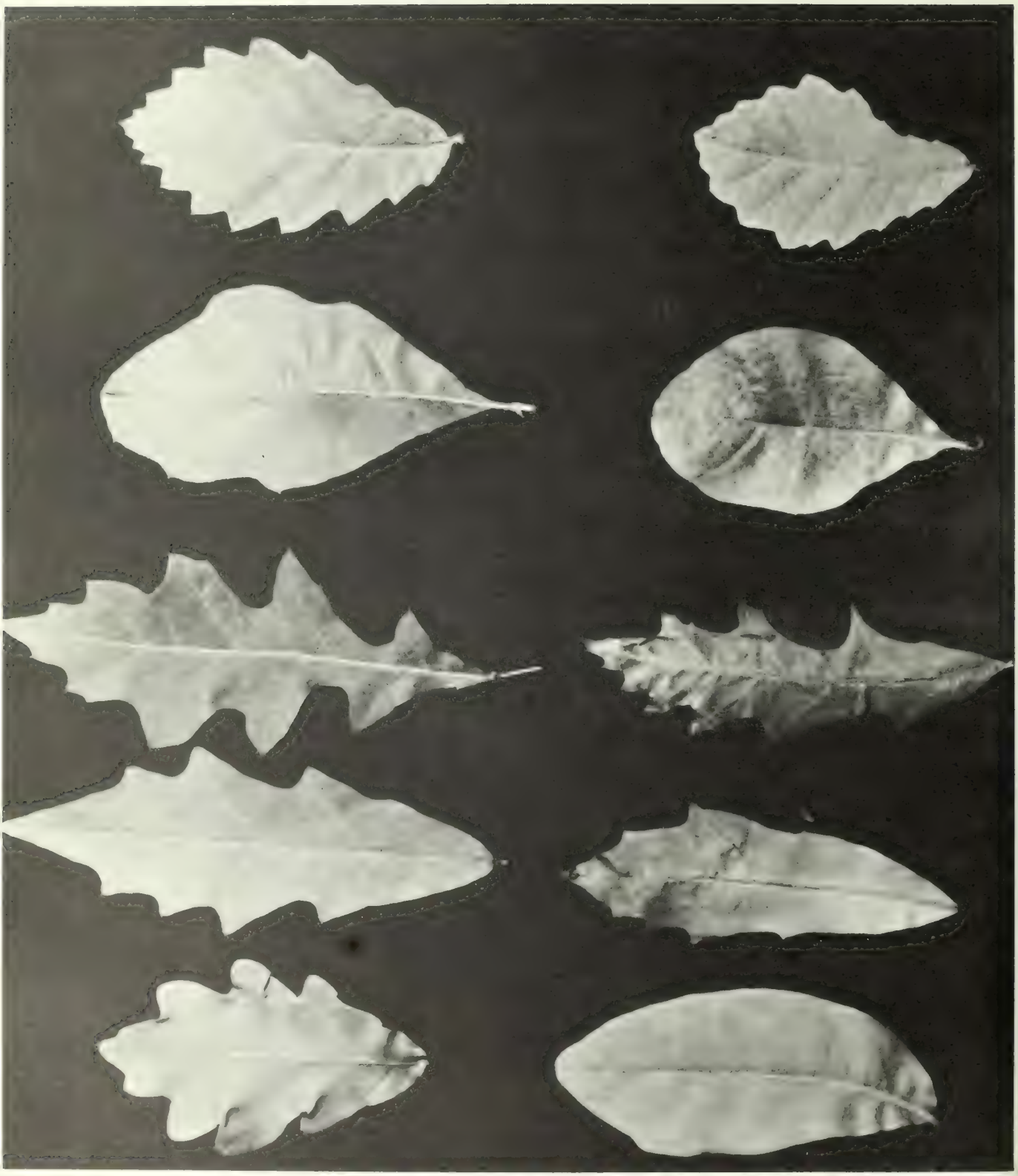
Buds.—Ovoid and flattened, giving triangular appearance; sharp-pointed; chestnut brown with narrow, darker brown bands on bud scale rims, occasionally almost entirely black; ⅛ inch long. Terminal buds lacking.

Table 4.—*Comparison of young red oak seedlings*

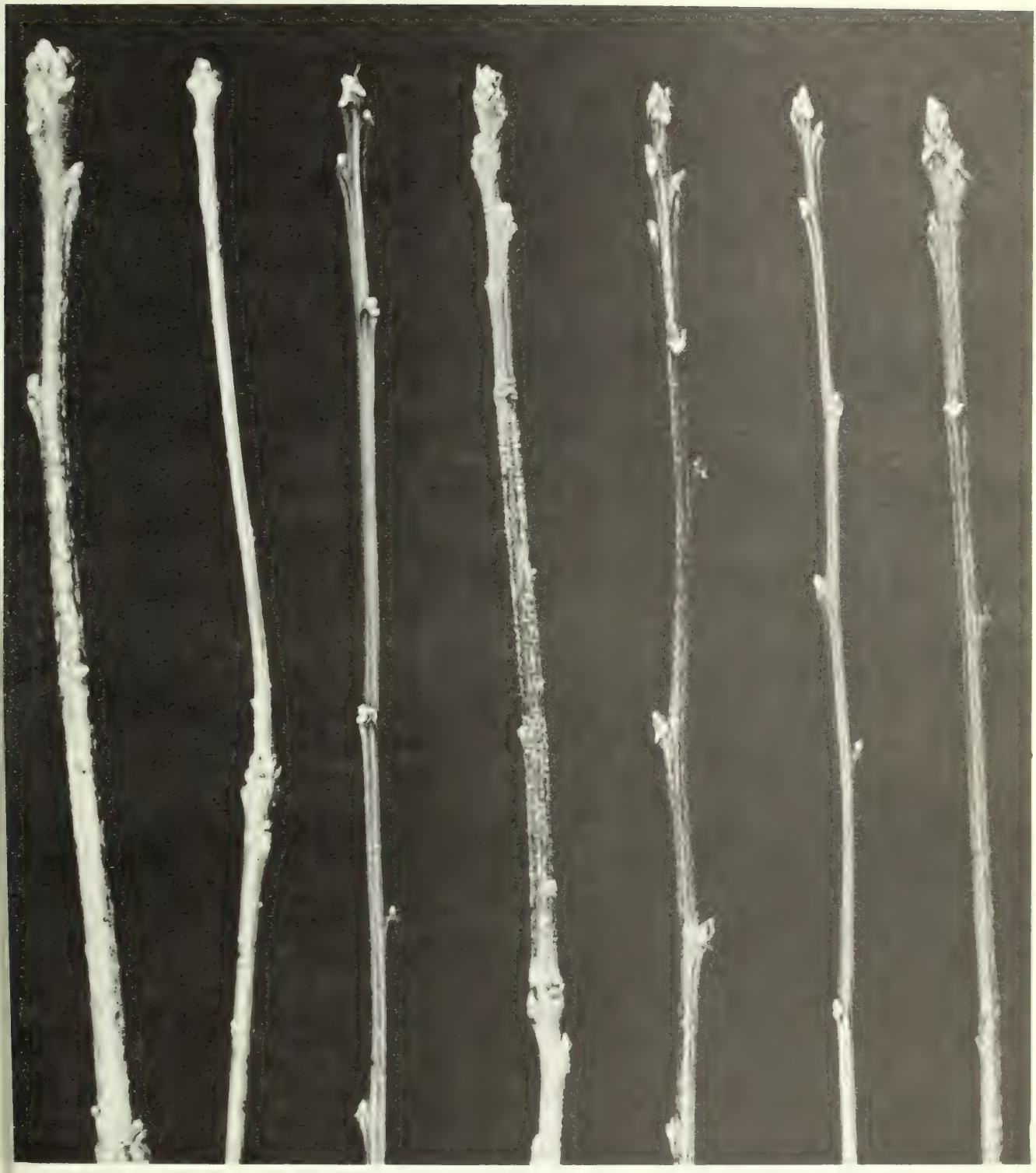
Species	Leaves		Stem pubescence	Buds		
	Color	Pubescence		Size	Pubescence	Color
Black oak	Dark green above, yellow-green below. Bright crimson when unfolding.	Scattered white hairs above, thick white hairs below. Brown hairs in vein axils.	Thick tawny hairs	½ inch long. Largest of species in this chart.	Downy with short tawny hairs	Dull tan
Cherrybark oak	Medium green above, paler below.	Fine down on lower surface	Heavy and gray	¼ inch long	Gray, moderate in amount	Red-brown
Shumard oak	Medium green, tinged with red when unfolding, later dark green	Tufts of hair in axils of veins on lower surface	None	¼ inch long	None	Grayish brown or dull straw
Southern red oak	Dark green above, pale gray-green below	Lustrous above, brown to grayish-white hairs below	Dense, rust-colored hairs at first, becoming sparser toward first winter	⅛ to ¼ inch long	Slightly downy with short pale hairs	Bright chestnut brown

Table 5.—*Comparison of young white oak seedlings*

Species	Leaves			Stem pubescence	Buds	
	Color	Pubescence	Margin		Pubescence	Color
Chinkapin oak	Medium green on upper surface, paler below	Smooth above, few gray hairs below	Coarse, large, sharp pointed serrations	Smooth to slightly coated with short white hairs	Absent	Chestnut-brown scales with white margins
Overcup oak	Dark green above, pale green or silvery below	Soft distinct hairs above and slightly downy beneath	Slightly lobed, sinuses very shallow	Slightly pubescent on appearance, becoming smooth later in year	Scales covered, especially near margin, with loose pale hairs	Light chestnut brown
Swamp chestnut oak	Bright yellow-green above, paler below	Thick coat white or rust-colored woolly hairs on under surface	Regularly scalloped with rounded lobes	Absent, except for slight coating of easily shed hairs near terminal end	Fine hairs along edges of bud scales	Light brown
White oak	When unfolding, bright red above, pale below. Later light green above, paler below.	Soft pubescence below, turning silvery white	Shallowly lobed at first, later becoming more noticeable	Covered with loose mass of brown colored hair	Smooth	Dark red-brown



Juvenile oak leaves at 8 weeks. X 1



Oak stems and buds at 1 year. X 1½

A Swamp chestnut
B Overcup
C Nuttall
D Southern red
E Water
F Willow
G Cherrybark

Black Oak
Quercus velutina Lam.
Family *Fagaceae*

Stem and buds at 2 months. Note pubescence and small white lenticels. X 2

At 1 month lobes are less noticeable than earlier. Note pubescence on upper surface and around margin of leaves. X ½

Juvenile leaves have undulating margin and lack definite lobes found on most red oaks. At 1 or 2 months, leaves are parchment-like in texture. The leaves of southern red and cherrybark oak are similar, but usually somewhat lobed and less leathery.

Cotyledons.—Do not appear above ground.

Leaves.—Simple; alternate to three in a whorl; ovate to obovate with rounded apexes and wedge-shaped bases; margins vary from almost entire to serrate on apical half with seven bristle-tipped teeth that develop into lobes by midseason. Upon unfolding, they are covered with dense, red, easily shed hairs above, and white hairs below. After a week, medium green and very finely pubescent with short white hairs on both surfaces. Leaf texture leathery toward close of first year.

Stem.—On appearance, reddish near base, changing to bright green near apex, and coated with short white hairs. By midseason, green to light purple and still pubescent. Cross section round throughout.

Buds.—Ovoid and slightly blunted at apexes; dull tan to light brown; tawny pubescent; ⅛ to ½ inch long, terminal buds largest. Cluster of buds at terminal is common.

Seedling 1 week after germination with bristle-tipped incipient lobes. X 1-1/4

Cherrybark Oak
Quercus falcata var. *pagodaefolia* Ell.
Family *Fagaceae*

Seedling at 1 week. X 1

Leaf shape is typical. Under surface of leaves is covered with white to light brown hairs. Young seedlings are easily confused with black, Shumard, or southern red oaks.

Cotyledons.—Do not appear above ground.

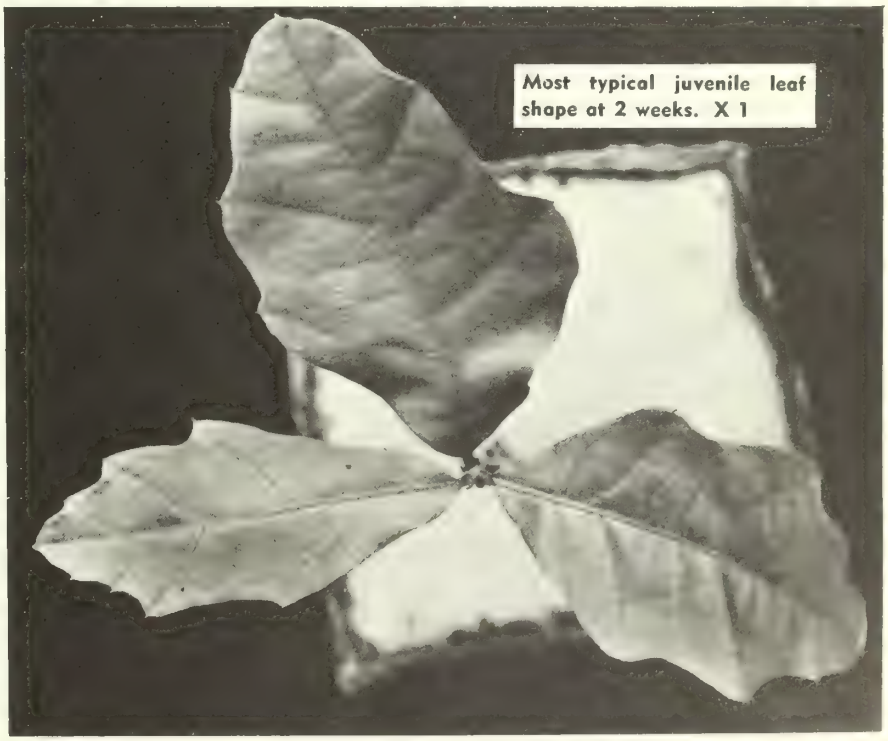
Leaves.—Juvenile seedlings have extremely variable leaf shapes. Most typical is broadly ovoid, about twice as long as it is wide, with rounded base and apex. Margins vary from nearly entire to undulate, bearing short bristles on tips of poorly defined lobes. Leaves sometimes have wedge-shaped or truncate bases and rounded sinuses of moderate or greater depth.

All leaves coarsely textured, medium green and lustrous above, paler green below, and densely covered with fine, white to tan hairs, especially during first growing season.

Stem and buds at 1 year. X 2

Stem.—Bright green during first few months, changing slowly, first at base, to reddish-brown. Heavily pubescent during first growing season, less so after first winter. Stem cross sections round throughout.

Buds.—Ovoid with acute points, about ¼ inch long, light red-brown, and moderately pubescent.

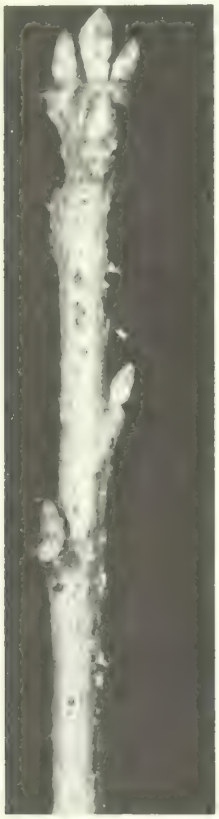


Most typical juvenile leaf shape at 2 weeks. X 1

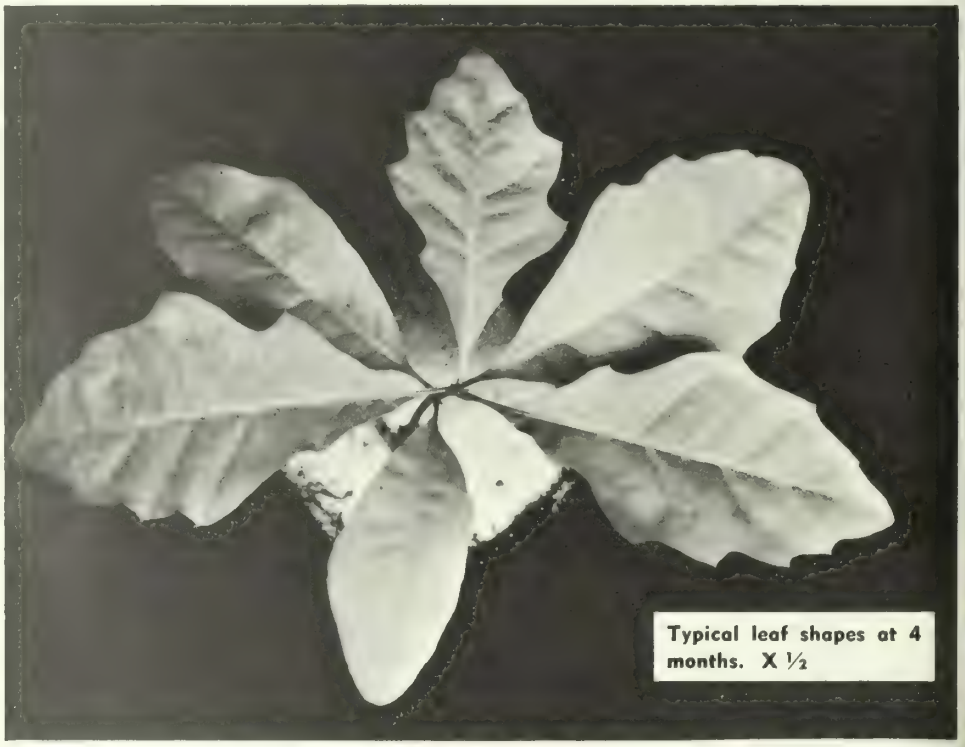
Shumard Oak
Quercus shumardii Buckl.
Family *Fagaceae*

Unfolding leaves have slight tinge of red, and the margins are sli undulate; upper surfaces have a few scattered short hairs, under sur are smooth. During the first year, seedlings are easily confused black, cherrybark, or southern red oaks.

Cotyledons.—Do not appear above ground.



Stem and buds at 1 year. X 2



Typical leaf shapes at 4 months. X ½

Seedling 10 days after germination. X 1

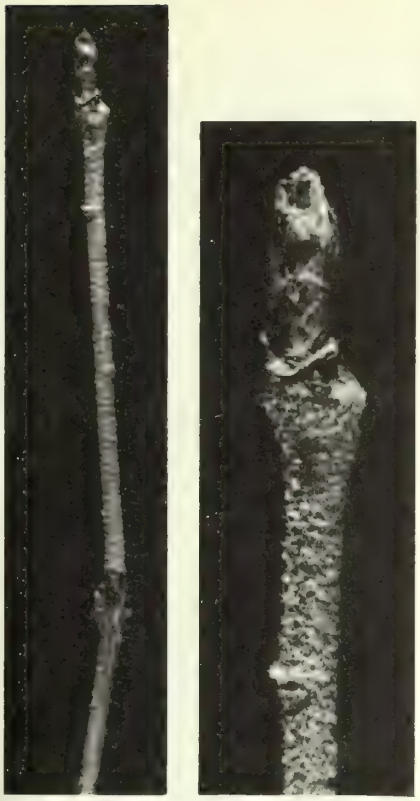
Leaves.—Simple and alternate. Seedlings less than a month old have elliptic leaves, about twice as long as wide, with slightly undulate margins bristled at tips of lobes. Upper surfaces dark green and have a few scattered short hairs; under surfaces paler and smooth.

Leaves of older plants typically obovate with rounded apexes and acute angled, narrow bases. Margins have short bristle-tipped lobes separated by rounded sinuses of varying depth. Upper surfaces dark green, smooth, and lustrous; under surface paler and smooth, except for tufts of hairs in axils of veins.

Stem.—Smooth, brownish-green or light gray, changing to gray or grayish-brown by midseason of first year. Cross section round throughout.

Buds.—Ovoid with acute apex, ¼ inch long, smooth, having closely overlapping gray-brown or dull straw-color scales. Resemble Nuttall oak buds but the two species usually occupy different sites.

Southern Red Oak
Quercus falcata Michx.
Family *Fagaceae*



Typical stem at 1 year moderately pubescent (left). X 1½. Terminal portion of stem at 1 year with pubescent terminal bud and stem (right). X 4

Leaf shape at 2 weeks. X1-1/4

Seedling at 1 month has varying type of leaf. X 6/10

Typical obovate-shaped leaves are dark green and shiny above, softly pubescent with light-colored hairs below. Margin is entire or with three or more broad lobes at apical end. Seedlings are confused with cherrybark and black oak in the juvenile period.

Cotyledons.—Do not appear above ground.

Leaves.—Simple; alternate; typically obovate, though sometimes ovate, with rounded apexes and wedge-shaped bases; margin entire or with three to seven rounded, bristle-tipped lobes on apical two-thirds of margin and separated by shallow, rounded sinuses; 3 to 4 inches long by 1½ to 2 inches wide at 6 months. As they unfold, covered with red, woolly hairs above and with less dense coating of white hairs below; changing after 2 months to dark green, smooth, and lustrous above, paler below and softly pubescent with light-colored hairs, especially along midrib and veins.

Stem.—Round; on appearance densely coated with easily shed short, red hairs, becoming light to reddish-brown and moderately pubescent on upper portion at end of first year.

Buds.—Broadly ovoid with blunt-pointed apex; slightly downy with short pale hairs; chestnut to reddish-brown; ⅛ to ¼ inch long; terminal buds largest.

Nuttall Oak
Quercus nuttallii Palmer
Family *Fagaceae*

Seedling 10 days after germination. X ½

Stem and buds at 1 year. X 1

Cross section of upper stem is angular. New leaves are usually deep red. Young overcup oak leaves are similar in size and shape but are never red.

Cotyledons.—Do not appear above ground.

Leaves.—First leaves appear within 2 weeks after germination. Simple; alternate; symmetrically 5- to 7-lobed, with lobes usually terminating in bristle-tipped teeth; leaf bases wedge-shaped. Usually deep red upon appearance but occasionally medium green. In 4 or 5 weeks upper surfaces become dull, dark green, lower surfaces paler green. Both

Stem.—Smooth during first year, olive green on lower portion, shading into reddish-brown or dark red near terminus. Upper portion angular in cross section.

Buds.—Less than ⅛ inch long, broadly ovoid, and gray. Color and small size unique among oak mixtures that include this species.

Chinkapin Oak
Quercus muehlenbergii Engelm.
Family *Fagaceae*

Stem at 1 year. Note bunching of axillary buds near stem terminal. X 2

Typical seedling at 9 months. X 1/4

Dark green leaves are thick and glossy. Margins have large, evenly spaced, sharp, recurved teeth.

Cotyledons.—Do not appear above ground.

Leaves.—Simple; alternate; oval to obovate with acute to rounded apex and wedge-shaped base; margin coarsely serrate with large, evenly spaced, frequently bristle-tipped, recurved teeth. Medium green on appearance with upper surface slightly hairy and coated below with white tomentum, later becoming dark green and lustrous above, slightly paler below; smooth on both surfaces and with prominent veins on lower side; 4 to 6 inches long by 1 to 3 inches wide.

Stem.—Round; on appearance, dark red to purplish with moderately heavy coating of short white hairs; by midyear, changing to olive-green near base and light brown on upper stem and smooth; marked by moderate number of small, round, white lenticels.

Buds.—Ovoid and blunt-pointed; reddish-brown scales with slightly pubescent edges that produce noticeable pattern on bud surface; 1/16 to ⅛ inch long, terminal ones larger than axillaries. Buds clustered at terminal end of twigs.

Leaf shape and size 2 weeks after germination. X 2

Overcup Oak
Quercus lyrata Walt
Family *Fagaceae*

Bud arrangement at 1 year. X 2

Upper surface of the leaves is dark green. Slight lobing is separated by very shallow, rounded sinuses. Seedlings are frequently confused with white oak, whose leaves are more deeply lobed and which is found on higher, better drained sites.

Cotyledons.—Do not appear above ground.

Leaves.—Upon unfolding, bronze-green with soft distinct hairs on upper side and thick pale hairs on under side. Simple; alternate; oblong-obovate; apex acute and base narrowly wedge-shaped; margin usually has seven to nine rounded lobes, broadest in middle, with sinuses rounded. After several weeks, upper surface dark green and smooth; lower surface pale green or silvery and slightly downy. Leaves occasionally resemble those of white oak but are less lobed, narrower, and more wedge-shaped at base.

Typical shallow lobing at 1 week. X 1

Stem.—Green or with a slight reddish tinge, and hairy or pubescent upon first appearance, becoming olive green or grayish brown and smooth toward end of first year. Cross section round throughout.

Buds.—Ovoid with blunt tip, about ⅛ inch long, with light chestnut brown scales covered, especially near margins, with loose, whitish hairs. Bud clusters form around terminal bud, but not as markedly as in cow oak.

Swamp Chestnut Oak
Quercus michauxii Nutt.
Family *Fagaceae*

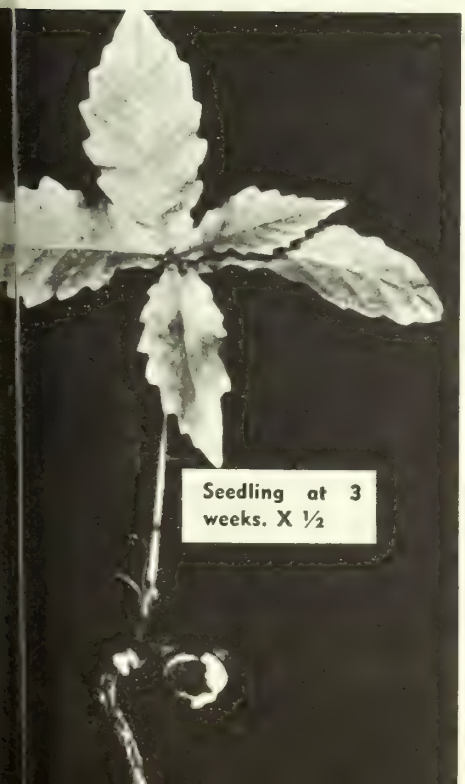
Typical leaf venation and pubescence at 6 weeks. X 1

Stem and buds at 1 year. X 1

Leaf shape and venation are typical. White or rust-colored woolly hairs cover the underside. Leaves resemble those of chinkapin oak, whose margins, however, are coarse and sharply serrate instead of wavy with very rounded teeth.

Cotyledons.—Do not appear above ground.

Leaves.—Simple; alternate; obovate to elliptic with acuminate apexes and rounded bases; margins undulately serrate with rounded teeth. Bright yellow-green, lustrous, and smooth on upper surface; under surface thickly coated with white or rust-colored woolly hairs. Leaf shape and venation are identifying characteristics in first few weeks after germination. Mature leaf size, 4 to 8 inches long and 1½ to 4 inches wide, may be attained toward end of first year.



Seedling at 3 weeks. X ½

Stem.—At 1 year generally smooth but covered near terminal with easily shed hairs. Color at first reddish-brown, changing to gray toward end of first year, especially at base. A few small, round, inconspicuous lenticels frequently found on upper stem.

Buds.—Terminal buds about ¼ inch long, broadly oval, dull-pointed, and light brown. Usually have fine hairs along edges of bud scales. Lateral buds same color and shape but about ⅛ inch long. Cluster of lateral buds around terminal is common.

Water Oak
Quercus nigra L.
Family *Fagaceae*

Small, dark green, wedge-shaped leaves are lobed after several months. Leaves persist on seedling until well into the winter.

Cotyledons.—Do not appear above ground.

Leaves.—May be confused with those of willow oak during first month or so before lobes develop. Simple; alternate; and for first month typically lanceolate to oblong-obovate with rounded apexes, wedge-shaped bases, and entire margins. Later frequently have broad, rounded and entire, or irregularly three-lobed, apexes; occasionally there is a single acuminate lobe below middle. Upon unfolding, leaves thin and light green, but within a few weeks they change to darker green above, paler green below; smooth on both surfaces.

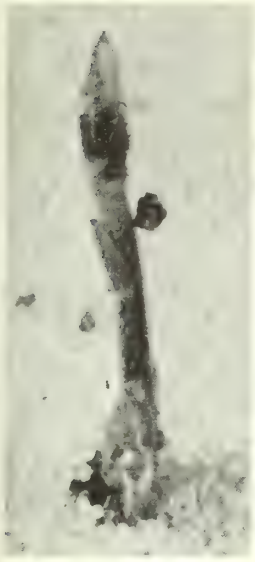
Stem.—Reddish-gray, smooth and round in cross section throughout.

Buds.—Ovoid, blunt-pointed, ⅛ to 3/16 inch long, with loosely overlapping dark red-brown scales. Sometimes very slightly hairy.

Seedling stem, and buds at 1 year. X 2

Juvenile seedling 2 weeks after germination. X 1

White Oak
Quercus alba L.
Family *Fagaceae*



Stem 3 days after emerging shows dense pubescence. X 2

Seedling 2 weeks after germination. Lobes are beginning to develop on leaves and there is an absence of bristles at lobe apexes. X ½

Stem and buds at 1 year. Buds cluster around the terminal, lenticels are sparse, and there is a slight angling of the cross section of the stem at the upper end. X 2

Leaves are light green; when lobed, they have rounded apexes and sinuses. Bristles are absent on lobe tips.

Cotyledons.—Do not appear above ground.

Leaves.—Simple; alternate to several in a whorl; oblong-obovate, gradually narrowing to wedge-shaped or rounded base. Margin undulate to slightly serrate for about 2 weeks, but not definitely lobed around upper half; later these leaves develop three to seven lobes with rounded sinuses. Upon unfolding, leaves covered on upper surface with dense red hairs and on under side with soft, pale pink to white pubescence; as hairs are shed, leaf becomes bright green above, blue-green and glaucous below.

Stem.—Olive green at first changing to gray by end of first year and covered with dense coating of short, red hairs. By midyear smooth, and a few small, round, white lenticels appear. Cross section round throughout, but slightly angled near terminal.

Buds.—Broadly ovoid and pointed; chocolate to reddish-brown; smooth; ⅛ to ¼ inch long; terminal buds largest. Cluster of lateral buds usually forms around terminal bud.

Willow Oak
Quercus phellos L.
Family *Fagaceae*

Seedlings appear conifer-like for several days after germination as the first leaves unfold. After 1 week, leaf shape is linear-lanceolate—the miniature form of mature foliage.

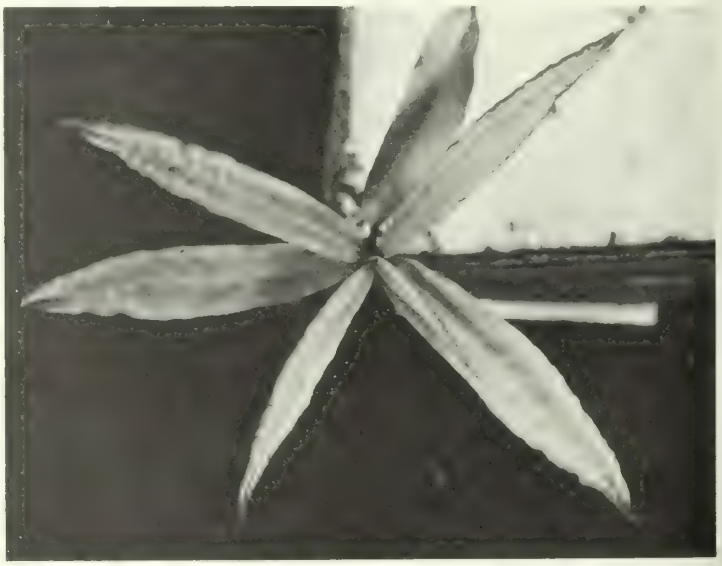
Cotyledons.—Do not appear above ground.

Leaves.—Simple; alternate; linear-lanceolate to elliptic with acute bristle-tipped apexes and rounded to wedge-shaped bases; margins entire. Both leaf surfaces smooth or slightly hairy along midrib. Upper surfaces dark green, lower surfaces usually paler.

Stem.—Reddish-brown and slightly pubescent for first few months, changing to gray and becoming smooth by end of first year. Round in cross section throughout.

Buds.—Ovoid, dull-pointed; chestnut brown; lateral buds 1/16 inch long, terminal buds ⅛ inch long.

Stem and buds at 1 year. X 2



Leaf detail at 2 weeks. X 1

Osage-Orange
Maclura pomifera (Raf.) Schneid.
Family *Moraceae*

Seedling development at 2 months. X 1/4

Cotyledons 4 days after germination. X 1

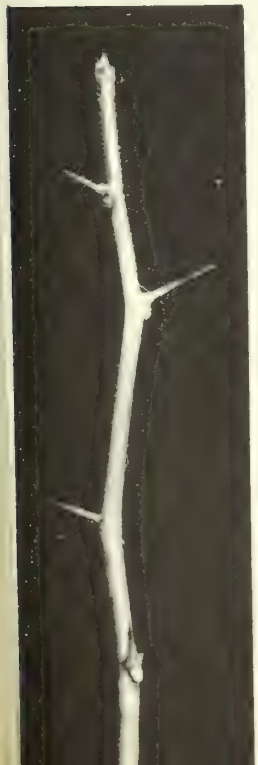
Dark green leaves are ovate-lanceolate and have a very shiny upper surface. The stem is armed with simple, stout thorns at each node. Plant exudes milky sap when crushed or broken.

Cotyledons.—Germinating seedlings emerge U-shaped from soil with seed coat covering cotyledons. Unfolding cotyledons shed seed coat within a few days and are broadly oval with rounded apex and base; dark green and smooth on both surfaces; single cotyledon ½ inch long.

Leaves.—First leaves appear within a week and are simple; alternate; ovate to ovate-lanceolate with acuminate apex having short, white bristle tip and rounded or occasionally slightly heart-shaped base; margin entire; dark green and lustrous on upper surface, paler below; smooth on both surfaces; 4 to 5 inches long and 2 inches wide at 2 months.

Stem.—Zigzag; round; olive green near base and gray-green above; covered with moderate amount of short brown hairs; and numerous small white lenticels. Simple, stout thorns ¼ to ½ inch long develop in each leaf axil after first 2 months. Exudes sticky, milky sap when cut or damaged.

Buds.—Terminal bud lacking; globose but slightly flattened and partly immersed in bark; light chestnut brown; minute, less than 1/16 inch in diameter; smooth.



Zigzag growth, spine development of stem and slight pubescence at 1 year. X 1½

Royal Paulownia
Paulownia tomentosa (Thunb.)
Sieb & Zucc.
Family *Bignoniaceae*

Stem and buds 1 year after germination. X 2

Ovate to nearly circular leaves have coarsely serrated margins and are very downy above and below. Pith is hollow or chambered.

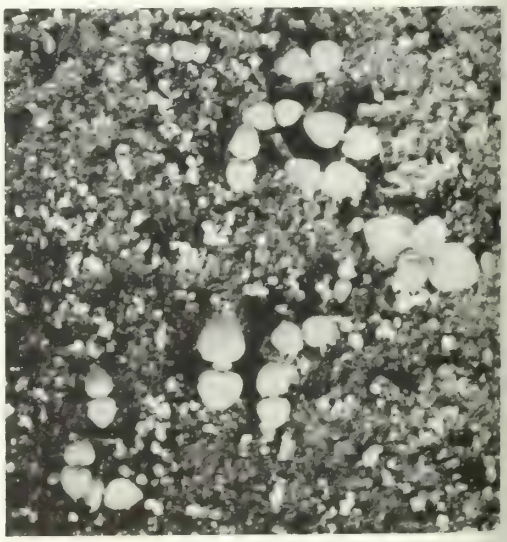
Cotyledons.—Minute on appearance; nearly round, truncate at base; light green and smooth on both surfaces; in 2 weeks attain diameter of ⅛ inch.

Leaves.—Appear within 2 weeks after germination; simple; opposite; broadly ovate to heart-shaped with acute to acuminate apexes and rounded to slightly heart-shaped bases; margin coarsely serrate throughout most of first year, later becoming entire. Medium green above and slightly paler below; both surfaces densely hairy and soft to touch; 2½ inches long by 1 to 1½ inches wide at 2 months; prominent venation above.

Stem.—Circular; olive green at first, becoming brown by year's end; marked with a few small, round to elliptical lenticels; slightly pubescent. Leaf scars round and pith hollow or chambered.

Buds.—Terminal bud lacking; ovoid; brown; moderate amount of light brown pubescence; 1/16 to ⅛ inch long.

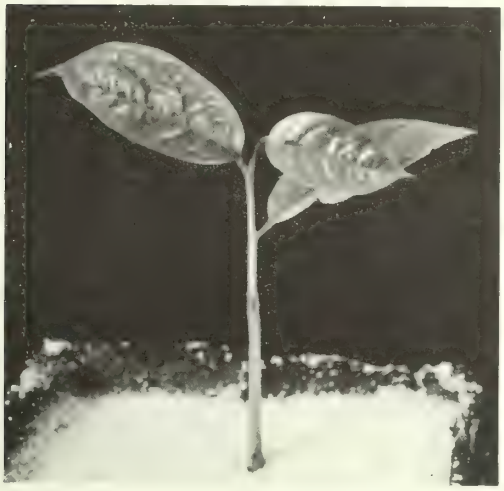
Typical leaves at 2 months. X 3/4



Cotyledon size and shape at 2 weeks. Largest plants already have first leaves. X 2½

Pawpaw
Asimina triloba (L.) Dunal
Family *Annonaceae*

Germinating plant (left) at 2 weeks. Apical end of stem is to the left. Leaves are still not released. A month after germination (right) the leaves are frequently still not entirely freed from the seed coat. Continuing stem development is pulling the seed out of the soil and may deform the plant. X 2



Seedling form and leaf characteristics 3 weeks after germination. X 1

Typical 1-year-old stem. X 2

Buds are soft, velvety, and chocolate-brown.

Cotyledons.—Do not appear above ground. First development stages of this species slow and difficult. Plant has trouble in extricating first leaves from tough seed coat that prevents cotyledons from separating. May take as long as a month after stem appears above ground; frequently entire germinating seed is pulled above ground by enlarging stem; growing point may be damaged, causing malformations.

Leaves.—Simple; alternate; ovate to ovate-lanceolate with acute to acuminate apexes and rounded to wedge-shaped bases; margin entire; medium green and rather shiny above, a little paler below; on appearance folded along midrib; when they unfold densely covered with rusty brown hairs on lower surface and slightly hairy above, becoming somewhat lighter in amount as leaves mature; 3 to 5 inches long by ¾ to 2¼ inches wide at 3 months. Prominent midrib and venation.

Stem.—Emerges from soil in inverted U-shape; circular; pink on appearance, changing to light brown streaked with light gray at 1 year; smooth to lightly pubescent.

Buds.—Ovoid, pointed at apex; dark brown and heavily covered with thick, rusty brown hairs making buds much darker than stem; ⅛ to ¼ inch long; terminal ones largest.

Pecan
Carya illinoensis (Wangenh.) K. Koch
Family *Juglandaceae*

No characteristics reliably separate this species from water hickory *(Carya aquatica),* the only other hickory seedling with which it is easily confused. Site is the best identification guide; water hickory is found on low wet flats, while pecan frequents riverfronts and ridges.

Cotyledons.—Do not appear above ground.

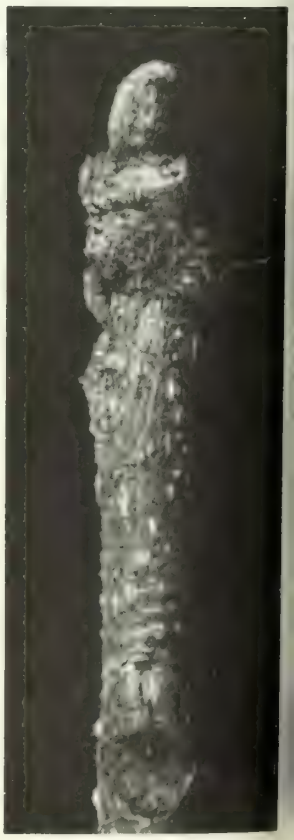
Leaves.—Alternate; simple; lanceolate to slightly obovate with acute apexes and rounded wedge-shaped bases; margins finely serrate. Dark yellow-green and usually smooth on both surfaces, though sometimes pubescent below; veins conspicuous. Typical pinnately compound leaves with single terminal leaflet of mature plants do not develop until near end of first growing season or in second year.

Stem.—On first appearance slightly tinged with red and covered with loose, pale hairs, later smooth or slightly hairy; marked in winter with numerous oblong pale lenticels and by large, oblong to roughly triangular, concave leaf scars. After several months, reddish-brown and slightly pubescent near terminal portion. Cross section round throughout.

Buds.—Winter buds red-brown; acute to slightly compressed and covered with clusters of light, jointed hairs; terminal buds ⅛ to ½ inch long, laterals 1/16 inch long.

Typical leaf arrangement and characteristics at 2 weeks. X ½

Stem and bud development at 1 year. Note size and frequence of lenticels and lateral buds. X 2



Terminal bud at 1 year. Note leaf scars. X 4

Common Persimmon
Diospyros virginiana L.
Family *Ebenaceae*

Heavy gray pubescence develops after several months on dark, reddish-brown stem.

Cotyledons.—Linear with bluntly rounded apex and wedge-shaped to rounded base; 1¼ inches long and 3/16 inch wide. Medium green and smooth above and below; persist on plant for 2 or 3 weeks.

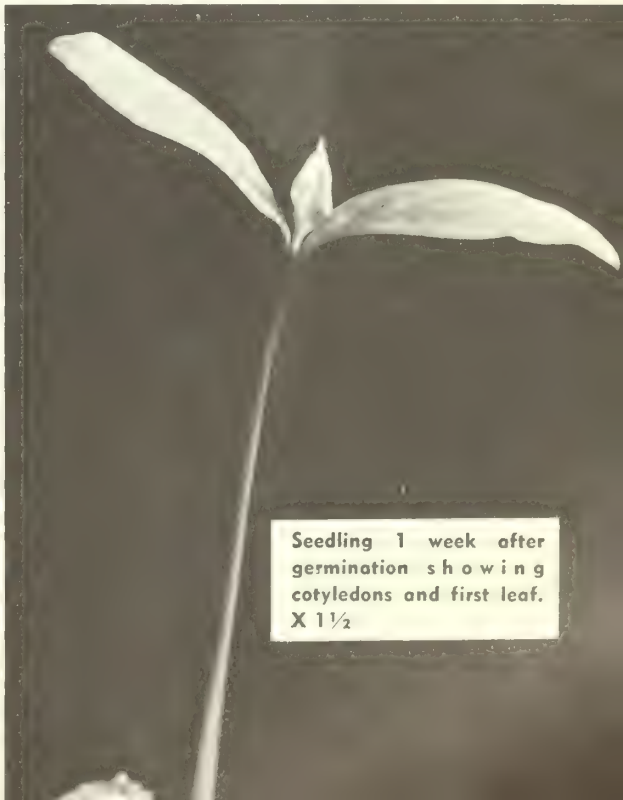
Leaves.—Appear by start of second week after germination. Simple; alternate; ovate-oblong to elliptic with acute or acuminate apexes and rounded or wedge-shaped bases; margins entire; smooth, dark green, and lustrous on upper surface, paler underneath.

Stem.—Light to reddish-brown when it first appears. Toward end of first year frequently ashy gray and marked by a few orange-colored lenticels and elevated, round leaf scars with deep horizontal crescent-shaped depressions; almost always heavily covered with short gray hairs. Cross section round throughout.

Buds.—Axillary, ovoid, acute, 1/16 to ⅛ inch long, with dark red or purple, lustrous scales.

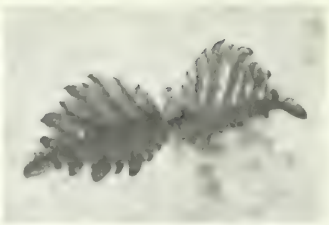
One-year-old stem with buds and lenticels. X 2

Typical leaf shape and growth 1 month after germination. X 1½

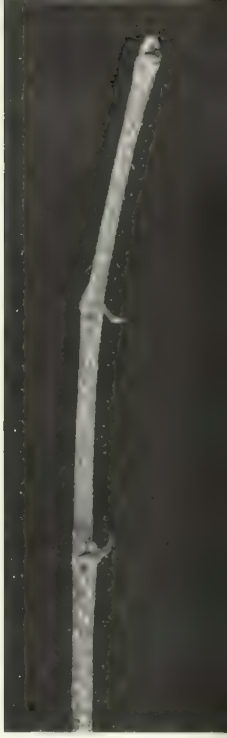


Seedling 1 week after germination showing cotyledons and first leaf. X 1½

Planertree (Waterelm)
Planera aquatica Gmel.
Family *Ulmaceae*



Seedling at germination. Cotyledons of this species remain in the soil. X 3



Stem and buds at 1 year. X 2

Seedling form and leaf characteristics at 3 months. X 3/10

Leaves are alternate and small. Corky ridges are absent on stem. Species is restricted to low, very wet sites. Cedar elm, the species with which it is most likely to be confused, also has small leaves but develops corky ridges in the latter half of its first year.

Cotyledons.—Failure to appear above ground excellent identification trait for seedlings only a few days old.

Leaves.—Simple; first pair opposite but all subsequent ones alternate; ovate to oblong-lanceolate with acute to obtuse apexes and rounded bases; margins coarsely doubly serrate; dark green and smooth on both surfaces at first, becoming rough on upper surface in latter half of first year. Leaves at terminal portion of stem often deeply tinged with red.

Stem.—Emerges from ground in U-shape; round; at first greenish-brown and smooth on basal portion, red and minutely pubescent on terminal portion. At 1 year reddish-brown with a few small, pale lenticels; slightly pubescent.

Buds.—Ovoid, obtuse; dark reddish-brown; pubescent; 1/16 inch long. Terminal buds lacking.

Heart-shaped leaves have palmate venation. The stem grows in a zigzag pattern.

Cotyledons.—Oval to nearly circular with rounded apexes and bases; medium green, smooth, and lustrous on upper surface, paler, dull, and smooth below; single cotyledon 3/8 inch long on appearance and grows little.

Leaves.—All leaves folded in half when emerging, and first ones appear within a week after germination. Simple; alternate; heart-shaped with abrupt obtuse or short, dull-pointed apexes; margin entire; palmately five- to seven-veined; yellow green at first, becoming medium green after a few weeks; smooth and lustrous on upper surface, dull and slightly pubescent along veins below; 1½ inches long by 1½ inches wide at broadest portion after 3 months.

Stem.—Growth zigzag; circular; brown; smooth and lustrous; conspicuously marked with numerous small, round, white lenticels; leaf scars nearly round.

Buds.—Ovoid with blunt-pointed apexes; brown and smooth; 1/16 to 1/8 inch long. Terminal buds lacking.

Zigzag growth pattern of 1-year-old stem. X 1½

Cotyledons at appearance. X 2

Leaves are folded in half when they emerge. X 3

Typical heart shape of completely unfolded leaf. X 4

Sassafras
Sassafras albidum (Nutt.) Nees
Family *Lauraceae*

At 1 year axillary buds set at acute angle with the stem. X 1½

Ovate, mitten-shaped, and three-lobed leaves are frequently present on the same plant. Crushed or broken leaves and stems exude aromatic odor.

Cotyledons.—Do not appear above ground.

Leaves.—Simple; alternate; ovate or elliptic with acute or obtuse apexes or lobes and wedge-shaped bases; margin entire, except that after midyear some mitten-shaped and three-lobed leaves with rounded sinuses may develop. Light to medium green above, paler below; smooth on both surfaces; 3½ inches long by 2 inches wide at 6 months. When crushed, give off aromatic odor.

Stem.—Round; deep red and smooth on appearance, becoming light green to reddish-brown at 1 year; leaf scars circular. Has aromatic odor when broken.

Buds.—Ovoid and sharp-pointed; red-brown; slightly pubescent; ⅛ to 3/16 inch long, terminal ones largest. Axillary buds set at acute angle with stem.

Seedling 3 days after germination. X 2

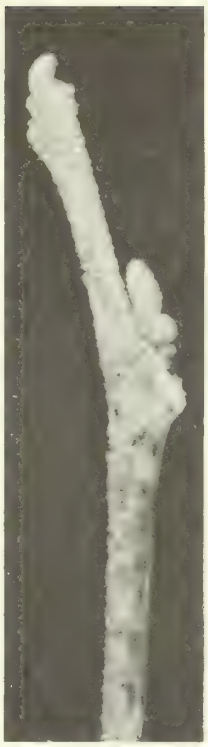
Lobed leaves beginning to appear at 6 months. X 1/4

American Snowbell
Styrax americana Lam.
Family *Styracaceae*

xillary buds are small and
t tan; one to three are super-
ed at each leaf scar. Terminal
s are lacking.

otyledons.—Oval to oblong
n rounded apex and slightly
ncate base; light green; smooth
both surfaces; venation prom-
nt; single cotyledon 3/8 to 1/2
n long and 1/4 inch wide.

eaves.—First leaves appear
in a few days after germina-
. Simple; alternate; oval to
e with acute to short-acumi-
apexes and rounded bases;
gin entire to very finely ser-
or sparsely toothed, especi-
around apical one-third of leaf.
er surface dark green and
oth, lower surface paler and
ately pubescent to smooth; pin-



Terminal portion of 1-year stem. Note superposed axillary buds and lenticels. Terminal bud lacking. X 4

nately veined; 2 to 3 inches long by 1½ inches wide at close of first year.

Stem.—Round; reddish-brown to gray and smooth on mature portion, green and finely pubescent on recent growth; marked with moderate amount of conspicuous elliptical, dark brown lenticels.

Buds.—Ovoid, slightly flattened with obtuse apex; light tan and with light pubescence; 1/16 to 1/8 inch long. Terminal buds lacking; one to three axillary buds superposed above each leaf scar.

Seedling late in first growing season. X 1/5

Cotyledons on first day after germination. Note definite venation. X 2½

Leaf shape and development at 2 weeks. X 1½

Spicebush
Lindera benzoin (L.) Blume
Family *Lauraceae*

Terminal bud has begun to open at 1 year. X 2

Leaf characteristics at 6 months. X ½

Typical seedling at 3 days. X 2

Oval, light green leaves have a soft texture and emi a spicy, aromatic odor when crushed. Buds are commonl collateral and superposed.

Cotyledons.—Do not appear above ground.

Leaves.—Simple; alternate; oval to ovate with acut to acuminate apexes and round to wedge-shaped bases margin entire; bright green and waxy-looking on uppe surface, paler below; smooth on both surfaces and with sof texture; 3 to 4 inches long by 1 to 2 inches wide at 6 months Emit spicy, aromatic odor when crushed.

Stem.—Emerges from ground U-shaped; lance-shape upon straightening. Circular and smooth; red-brown a first, changing to olive-brown on older portion of stem after a few months; marked by a few small, round white lenticels and circular leaf scars. Has aromatic taste.

Buds.—Elongated ovoid with pointed apexes; dark brown and smooth; 1/16 to ⅛ inch long. Commonly collateral and superposed, upper one the best developed.

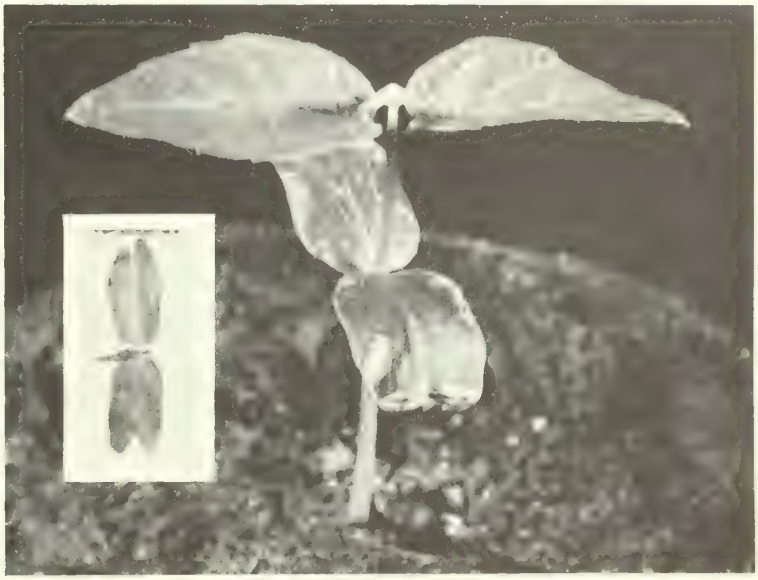
Sugarberry
Celtis laevigata Willd.
Family *Ulmaceae*

Near terminal portion of 1-year-old stem with branching habit and lenticels. X 1

Cotyledons are notched. Upper surface of leaves is rough. Flat, spray-like appearance of young seedlings results from alternate twig arrangement in the same plane.

Cotyledons.—V-shaped notch in apex of cotyledons identifies genus but does not distinguish between sugarberry and hackberry. Basal end slightly rounded and petiole very short. Cotyledons remain attached for at least 1 month after germination.

Leaves.—Closely resemble those of mature trees but smaller, with more serrated margins. Simple; alternate; for first half year short, ovate with blunt-pointed apexes



Typical notched cotyledon (inset). X 1. Seedling at 1 week. X 2

Typical juvenile leaves and plant form at 2 weeks. X 1

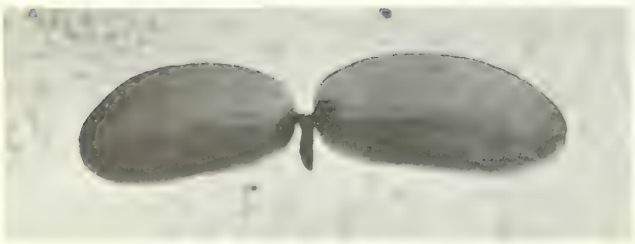
and rounded or slightly heart-shaped bases; rough upper surfaces; light green, sometimes paler underneath. Later leaves more nearly oblong-lanceolate, with sharp apexes and frequently less serrated margins, especially around lower half. Three veins arise at base and extend to near tip.

Stem.—At 1 year light green to reddish-brown; bark thin, smooth, and often marked with small, round, white lenticels on lower portion. No warty outgrowths as on older trees. Lateral twigs alternate and all in same plane, producing effect of flat spray and giving plant delicate appearance.

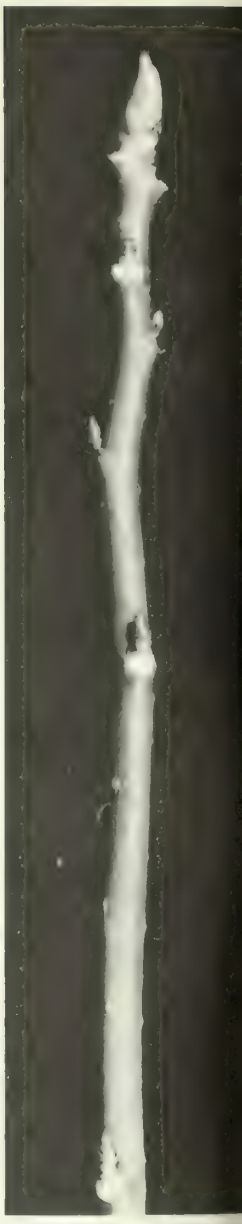
Buds.—In winter reddish-brown, 1/16 to ⅛ inch long, ovoid and pointed.

Sweetgum
Liquidambar styraciflua L.
Family *Hamamelidaceae*

Three-week-old seedlings exhibit typical 3-lobed leaves and persistent cotyledons. X 1



Cotyledons 1 week after germination. First leaf just beginning to unfold. X 2



Stem and buds at 1 year. Note appearance of lenticels and bud arrangement. X 2

Casual observer may confuse leaves of seedlings less than 6 months old with those of red maple and boxelder. Red maple stems are smooth and red; boxelder stems are bright green, shiny, and smooth; sweetgum stems are green and covered with red hairs. After 6 months, the typical five-pointed, star-shaped leaves appear.

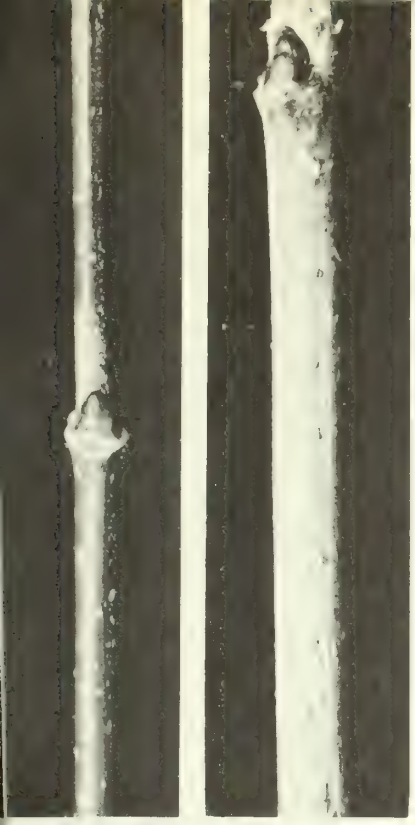
Cotyledons.—Medium to dark green; elliptical with prominent midrib; persist on developing plant for several months.

Leaves.—First leaves appear within week or two after germination, mostly with three blunt-pointed lobes and truncate or slightly heart-shaped base; margin coarsely serrate. Simple; opposite for first few pairs, but alternate after midseason, hairy underneath upon unfolding, but soon becoming smooth except for tufts of short white hairs in axils of principal veins; bright to less bright green on both surfaces but glossier above. Five-lobed, star-shaped leaves appear in 6 months or more.

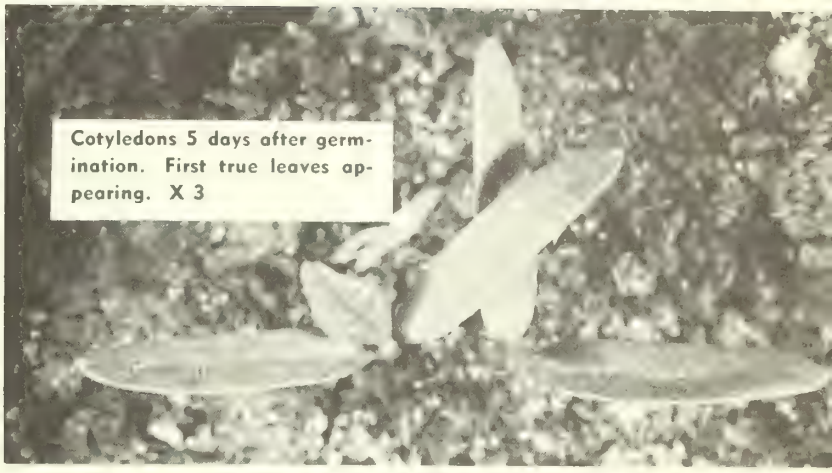
Stem.—Light green beneath mass of easily shed red-brown hairs, changing to light brown by end of first year. Marked with occasional pale lenticels and bow-shaped leaf scars showing ends of three conspicuous fibrovascular bundles. Cross section round throughout.

Buds.—Reddish-brown, ovoid, acute, smooth. Terminal buds ¼ inch long, lateral buds about 1/16 inch long.

American Sycamore
Platanus occidentalis L.
Family *Platanaceae*



ne-year old stem and buds. Lenticels nd lateral bud on upper portion of stem eft). Note leaf scar surrounding the bud. ypical lighter color of basal portion of em and size and shape of lateral buds ight). X 2



Cotyledons 5 days after germination. First true leaves appearing. X 3

Seedling 3 months after germination. X ½

Large leaves are coarse-toothed and maple-like after midseason. They are pubescent along the veins underneath.

Cotyledons.—Lanceolate with blunt rounded apexes and bases; dark green and smooth on both surfaces; ½ inch long and ⅛ inch wide within 2 days. Persist on seedling for a month or two.

Leaves.—Simple; alternate; broadly ovate with acuminate apexes and wedge-shaped bases; margins during first few months coarsely serrate. Later develop five short, sinuate, acuminate lobes also coarsely serrate. Upon unfolding, bright green, glossy, and smooth above and a little paler below; hairy along midrib and veins. Texture becomes leathery as leaf matures.

Stem.—On appearance, red and heavily pubescent; after several months smooth and dark to olive green, especially near base, and marked with frequent oblong pale lenticels. Cross section round but slightly angled near terminal.

Buds.—Covered by hollow base of leaf petioles; broad ovoid, blunt-pointed; smooth; red-brown; ⅛ to ¼ inch long.

Tallowtree
Sapium sebiferum (L.) Roxb.
Family *Euphorbiaceae*

Leaf shape variations at 1 month. Opposite arrangement is infrequent. X 3/4

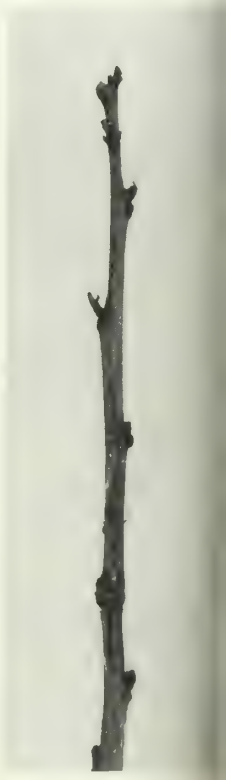
Rhombic, dark green leaves turn bright red or yellow before leaf fall on most trees. Milky sap is poisonous.

Cotyledons.—Oblong with truncated apexes, gradually tapering to wedge-shaped bases; dark green and smooth on both surfaces; individual cotyledon ¾ inch long by ⅜ inch wide. Generally remain on plant less than 1 month.

Leaves.—First leaves develop about a week after germination. Simple; first pair opposite, later ones usually, but not always, alternate; chiefly rhombic, occasionally round to oval, with round to abruptly acuminate apexes and round to wedge-shaped; margin entire; dark green and smooth on upper surface, paler and duller below. At 1 month, blades are 1 to 2 inches long by 1 inch wide on petioles of nearly equal length. Turn bright red or yellow before they drop in fall but may remain green on some plants.

Stem.—Emerges U-shaped from soil; circular; dark green to reddish at first, becoming gray-brown on mature portion by autumn; smooth; marked with many small lenticels. Stem surface roughened by closely spaced, elevated, oval to roughly triangular leaf scars.

Buds.—Broad ovoid and blunt-pointed; red-brown and smooth; 1/16 inch long.



One-year-old stem with typical alternate arrangement of axillary buds above leaf scars. X 2

Cotyledons at 1 week. X 2

Black Tupelo (Blackgum)
Nyssa sylvatica Marsh.
Family *Cornaceae*

Oval to ovate leaves are medium to dark green and shiny above. They usually are remotely toothed on the top one-third of the margin and turn bright red in early fall while leaves of other trees are still green.

Cotyledons.—Ovate to elliptical, tapering slightly to rounded apexes and with rounded bases; dark green and smooth on both surfaces; single cotyledon about 1 inch long by ½ inch wide on appearance. Make little growth but persist on plant for as long as 3 months.

Leaves.—Simple; alternate; ovate or slightly obovate with short acuminate apexes and wedge-shaped to rounded bases; margin entire to remotely and shallowly toothed around apical half of leaf; dark green, shiny and smooth above, paler below; slightly pubescent with short, soft, white hairs on appearance, becoming smooth after several weeks; 3 to 4 inches long by 1 to 1¼ inches wide at 6 months.

Stem.—Round; smooth; dark red on appearance, changing to greenish gray at base; new growth light green after several months and greenish-brown tinged with red-brown by first winter. Marked by a few scattered pale lenticels and with small lunar-shaped leaf scars.

Buds.—Ovoid; obtuse; moderate to dense coating of short, silky white hairs; terminal buds most pubescent; gray green to dark red brown. Axillary buds minute, terminal ones ⅛ to 3/16 inch long.

Cotyledons on appearance. X 2

Stem and buds at 1 year. X 2

Typical leaf shapes 6 months after germination. X ½

Water Tupelo
Nyssa aquatica L.
Family *Cornaceae*

Stem and buds at 1 year. X 1½

Typical cotyledons 1 week after germination. X 1-1/3

Seedling at 1 month. X 3/4

Seedlings closely resemble those of black tupel but the leaves are larger and the stems dark red A tree found mainly on very wet sites.

Cotyledons.—Elliptical to lanceolate with blun pointed apexes and rounded bases; dark green smooth, and prominently veined; single cotyledo 2½ inches long by ½ inch wide, grows consider ably before being shed 2 to 3 months after germ ination.

Leaves.—Simple; alternate; oblong to oval with acute to acuminate apexes and wedge-shaped t rounded bases; margin entire or irregularly toothed; light red and pubescent on both surface on unfolding, later dark green, lustrous and smooth above, paler and with downy pubescence below; 2 to 3 inches long by ½ to 1 inch wide after a month or two.

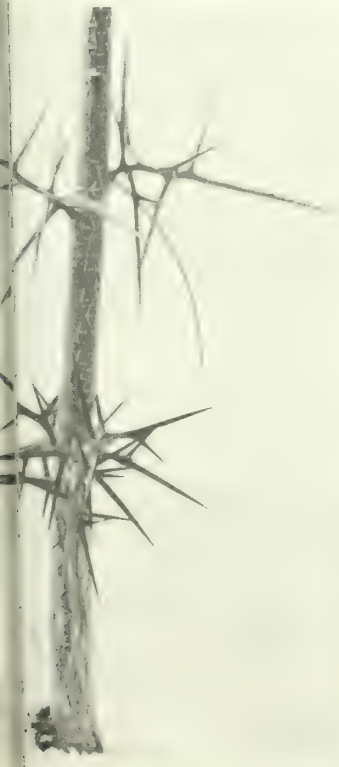
Stem.—Emerges U-shaped from soil; round dark red on appearance, but becoming lighter with maturity and reaching a light or bright red brown by first winter; smooth; marked by small scattered pale lenticels and by conspicuous ele vated, nearly round leaf scars.

Buds.—Terminal buds more or less globular; slightly pubescent; red brown; ⅛ to ¼ inch long. Axillary buds minute, obtuse, nearly embedded in bark.

Waterlocust
Gleditsia aquatica Marsh.
Family *Leguminosae*

Cotyledons shortly after appearance. X 2

One-month-old seedling with opposite and alternate leaflet arrangement and first developing spines. Cotyledons still persistent. X 1



horn development by midyear. horn clusters near the base of e stem are typical and a useful lentification characteristic for this ecies. X 1

Upper stem, buds, and thorns at 1 year. X 2

Leaflets are small and mimosa-like. Branched thorns develop early on the stem, and their characteristic bunching near the stem base occurs by the latter half of the first year.

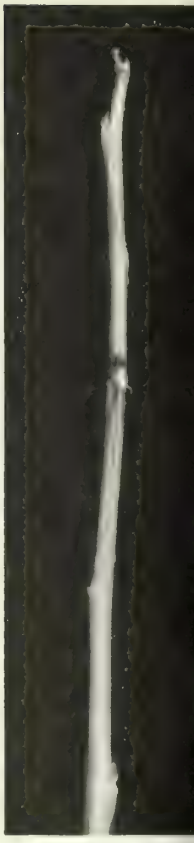
Cotyledons.—Oval and rounded at both ends; dark green and smooth on both surfaces; single cotyledon ½ inch long and ⅝ inch wide on appearance; grows little. Persist on stem for as long as 2 months after germination.

Leaves.—First leaves appear within a few days. Alternate; pinnately compound during first year; 2¼ to 4¾ inches long by midyear. Leaflets 20 to 40, opposite or alternate on rachis; nearly sessile; ⅜ inch long by ⅛ inch wide; ovate-oblong with rounded apexes and bases; margin with small, rounded teeth to entire; medium green and smooth on both surfaces.

Stem.—Circular; pale green; smooth and marked with small white lenticels. Noticeably zigzag and armed with many dark red-brown, stout, rigid, three-pronged or multiple short-branched thorns, ½ to 1 inch long at midyear. Thorn development first noticed just above leaf axils; it may begin as early as 1 week after germination and is much earlier than on honeylocust. Formation of clusters of thorns on lower stem is excellent guide in separating waterlocust seedlings from those of honeylocust (see honeylocust photo).

Buds.—Reddish to dark brown; spherical; smooth; terminal bud lacking; axillary buds minute and inconspicuous.

Black Willow
Salix nigra Marsh.
Family *Salicaceae*



Stem and buds at 1 year. X 2

Cotyledons are nearly round to slightly heart-shaped for the first month. The appearing leaves are lanceolate rather than heart- or triangular-shaped, as are leaves of eastern cottonwood, with which they are sometimes confused.

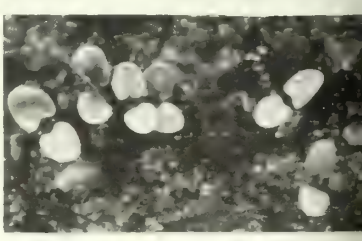
Cotyledons.—Nearly round or slightly heart-shaped with rounded apexes, opposite on olive green, smooth stem. Blades, medium green on both surfaces, 1/16 inch in diameter, persist on stem for about a month.

Leaves.—First leaves, which appear at end of a week, are simple and opposite on growing stem, but in a week or two are alternate, as on mature plant. In this stage, easily confused with eastern and swamp cottonwood, but leaves more lanceolate than cottonwood; this difference even more marked later in season. Medium to light green on both surfaces, smooth, narrow lanceolate with sharp-pointed apexes and wedge-shaped to rounded bases, margins finely serrate. Stipules variable—either large, foliaceous, persistent, or small, ovate, deciduous.

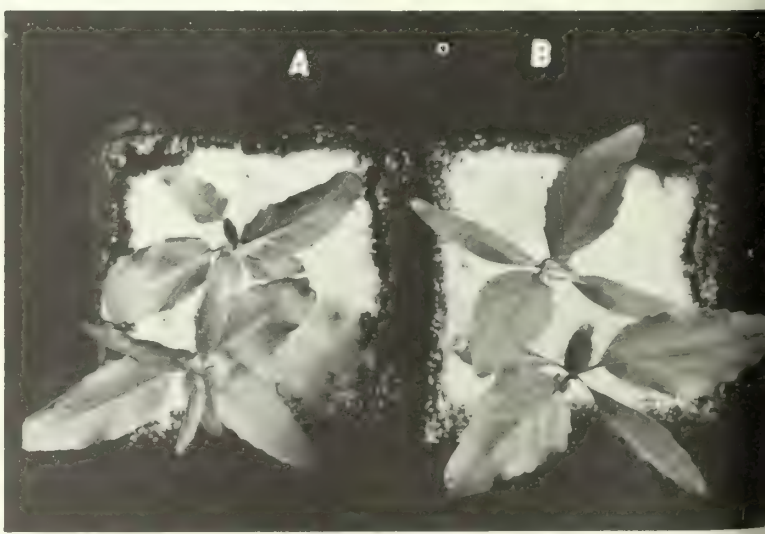
Stem.—Slightly hairy at first, but soon smooth and shiny; olive green, merging to reddish-brown on upper portion; slender and brittle. Cross section round throughout.

Buds.—Length 1/16 to ⅛ inch, triangular and acute, red to red-brown. When present, stipule scars nearly encircle the stem.

Seedling at 2 months. X 1/3



Cotyledons 2 days after germination. X 3



Leaf shapes 3 weeks after germination. (A), Black Willow. (B), Eastern cottonwood. X ½

Sandbar willow
Salix interior Rowlee
Family *Salicaceae*

Typical seedlings at 2 months. X ¼

Cotyledons and first leaves at 10 days. Cotyledons are without petioles. X 2

Stem at 1 year. Buds have begun to open. Note scattered lenticels. X 2

Sandbar (upper) and black willow (lower) leaf serrations at 2 months. X 1-1/10

Small, narrow lanceolate leaves have coarsely toothed margins, 8 to 10 serrations per inch. In contrast, leaves of black willow, with which this species may be confused, are finely serrate.

Cotyledons.—Elliptical, about twice as long as wide, with rounded apexes and bases; medium green and smooth on both surfaces; very small on appearance and only about ⅛ inch long after 10 days. Persist on stem for less than 1 month. Difficult to tell from those of black willow, which are more nearly round.

Leaves.—First leaves appear within 10 days after germination. Simple; alternate; linear-lanceolate and quite narrow with acute to long pointed apexes and wedge-shaped bases; margin for first few weeks coarsely lobed but in 2 months develops regular sharp-pointed serrations with widespread teeth. Dark green and smooth on both surfaces; 2 to 3 inches long by ¼ to ½ inch wide in 2 months. Coarse serrations of leaves make possible easy and early separation of this species from black willow.

Stem.—Round; smooth; light green at first, turning dark orange or reddish-brown by end of first year; marked by widely scattered, long, elliptical white lenticels and raised, triangular to lunar-shaped leaf scars.

Buds.—Narrowly ovoid, acute; smooth; chestnut brown; 1/16 to ⅛ inch long.

Yellow-poplar
Liriodendron tulipifera L.
Family *Magnoliaceae*

Typical medium green leaves are four-lobed. Large buds are enclosed by valvate scales that separate to reveal folded leaf.

Cotyledons.—Elliptical with slightly pointed apexes and rounded bases; smooth; medium green; about ¾ inch long 2 weeks after appearance. Persist on plant for as long as 2 months.

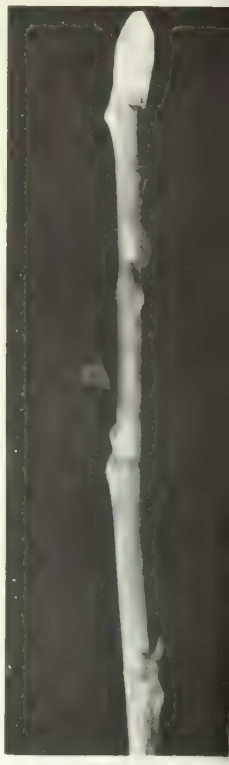
Leaves.—First leaves appear within 2 weeks after germination. Simple; alternate; roughly circular, those appearing in first 2 months are heart-shaped with no distinct lobing; later ones broken into four

Typical leaf shape after 2 months. Note folded leaves and prominent foliar stipules. X 2

definite lobes; all leaves on appearance folded in half along midrib; apexes broadly notched and bases are truncate to rounded or heart-shaped. Margins entire; dark green above, slightly paler below; smooth on both surfaces; about 2 inches in diameter 2 weeks after appearance.

Stem.—Round throughout; reddish-brown; shiny, smooth; often covered with white, waxy-looking bloom; roughened by nearly circular leaf scars and stipule scars encircling twig. Scattered white lenticels also present.

Buds.—Terminal buds with valvate scales; flattened or "duck-billed;" reddish-brown; smooth, with waxy-looking bloom; ½ inch long. Axillary buds much smaller, and ovoid with blunt-tipped apex.



Stem and buds at 1 year. X 1

Terminal bud at 1 year. Note valvate bud scales and the stipule scar encircling the stem. X 4

References

Brown, C. A.
1945. Louisiana trees and shrubs. La. Forest. Comm. Bull. 1, 262 pp.

Little, E. L., Jr.
1953. Check list of native and naturalized trees of the United States (including Alaska). USDA, Agr. Handbook 41, 472 pp.

Moore, D. M.
1960. Trees of Arkansas. Ark. Forest. Comm., 128 pp.

Putnam, J. A., and Bull, H.
1932. The trees of the bottomlands of the Mississippi River Delta region. USDA Forest Serv. South. Forest Exp. Sta. Occas. Pap. 27, 207 pp.

Sargent, C. S.
1926. Manual of the trees of North America (exclusive of Mexico). Ed. 2, 910 pp. Boston and N. Y.: Houghton Mifflin Co.

Vines, R. A.
1960. Trees, shrubs and woody vines of the Southwest. 1104 pp. Univ. Tex. Press, Austin.

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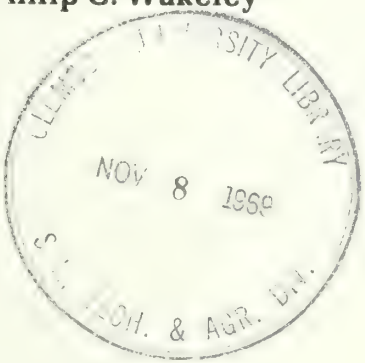
Single Commercial Thinnings in Variously Spaced Slash and Loblolly Pine Plantations

Philip C. Wakeley



Southern Forest Experiment Station
Forest Service
U. S. Department of Agriculture

1969

Single Commercial Thinnings in Variously Spaced Slash and Loblolly Pine Plantations

Philip C. Wakeley

In mid-June of 1940, the Southern Forest Experiment Station applied light and heavy thinnings to slash pines *(Pinus elliottii* Engelm.) that had been planted the winter of 1924-1925 at spacings of 8 by 8, 6 by 6, and 5 by 5 feet. Early in March 1942 it made similar thinnings in loblolly pines (*P. taeda* L.) that had been planted at the same spacings in 1922-1923. Final measurements were at age 30 years in the slash plantations, and at age 34 in the loblolly.

The thinnings could not be shown to have affected significantly the pulpwood yields within any one spacing of either species. Nevertheless, their simultaneous application to three spacings, their comparison with unthinned checks, and their final measurement at the end of practicable pulpwood rotations have provided information not available from previous studies of shorter duration.

The Plantations

Plantations of the two species were established in separate areas near Bogalusa, in southeastern Louisiana.[2] Each spacing of each species was tested on a single, square 1.0-acre plot on open, grassy, slightly brushy sites on which heavy stands of old-growth longleaf pine (P. *palustris* Mill.) had been clearcut and skidder-logged in 1918 or 1919. Uncontrolled fires were frequent on both areas until about 1920, but none occurred thereafter. Fifty-year site-index values, as determined from mean heights of the dominant and codominant plantation trees at final measurement, ranged from 81 to 88 feet for slash pine and from 79 to 82 for loblolly (7).

Planting was in shallow furrows, with 1-0 nursery stock. Survival of the slash pine ranged from 84 to 88 percent at the end of the first growing season; at that time, to maintain regularity of spacing, the fail spots were replanted with 1-0 seedlings. Survival of the loblolly pine ranged from 69 to 73 percent at the end of the second growing season, and the

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The author is retired from the Forest Service, USDA. While on the staff of the Southern Forest Experiment Station he did or supervised all the work on the plantations described here, except planting the loblolly pine.

The land was owned by the Great Southern Lumber Company, which, with its successor, Gaylord Container Corporation, cooperated throughout the experiment by supplying nursery stock, protecting the plantations, furnishing labor for thinnings, and helping make the final measurements. Crown Zellerbach Corporation has since succeeded Gaylord as owner of the land.

fail spots were then replanted with 1-0 stock. Both original and replacement loblolly trees were of local provenance, and all the slash pines were from seed collected near Lake City, in northeastern Florida.

In mid-June of 1940, after the slash pines had started their 16th growing season in plantation, heavy and light thinnings and unthinned checks were established in latin-square design in each of the three spacings; the thinned plots and unthinned check plots averaged approximately 0.11 acre in size. Similar treatments, in similar design, were established in each of the loblolly spacings after the 19th growing season. The design provided three observations on which to base each mean in the tables that follow.

Throughout the study the stands were protected not only from wildfire but also from grazing and accidental cutting.

Prethinning measurements, were made at age 15 in the slash plantations and at age 18 in the loblolly. They included survival, d.b.h., and cut-versus-leave status of all trees, but heights of sample trees only. Final measurements at age 30 in the slash plantations and at age 34 in the loblolly included plantation survival and the crown class, d.b.h., total height, pulpwood heights, sawtimber height, and degree of fusiform-rust infection of every living tree. All records throughout the study were kept separate by individual trees.

The time lapses (3 months in slash; 1 year in loblolly) between prethinning measurement and thinning, together with the layout of the plantations, imposed three limitations on analyses of results. 1.—Values for volumes salvaged in thinning, for volumes and mean diameters of stands left after thinning, and for total pulpwood produced on the thinned plots were scant by the amounts of wood formed between prethinning measurement and thinning. 2.—Because spacings were not replicated within species, no error term was available for testing the significance of differences attributable to spacings. 3.—Although the latin-square design of thinning treatments within spacings provided error terms for testing the significance of differences attributable to thinnings, the tests were relatively insensitive, with only 2 degrees of freedom for treatments and 2 or 6 for error. Some differences properly attributable to thinnings may therefore have escaped detection.

In interpreting both prethinning and final measurements, the volume discrepancies that resulted from the time lapses have been disregarded. Probably none of these discrepancies exceeded 3 percent, and within either species they must have affected all spacings and thinnings about equally. The two other limitations noted above were compensated for, in part, by certain well defined and suggestive trends among all species × spacing × thinning-treatment combinations. These trends are described later in connection with individual variables.

Experimental Thinnings

Both light and heavy thinnings were commercial in that they yielded at least 2.6 cords of pulpwood per acre. Both, however, included some trees below pulpwood size; and the light thinnings, particularly at 5- by 5-foot spacing, where diameter growth had been poorest, removed most or all of such nonmerchantable trees.

The light thinnings at age 15-plus in slash pine and at age 19 in loblolly were patterned after those then being applied in nearby 13- to 18-year-old commercial plantations at 6- by 8-foot spacing. The intention was to cut 30 percent of all trees by stem count, regardless of survival percent prior to thinning, but in fact 28 to 40 percent of all trees were removed. Light thinning was almost entirely from below, but included a few large trees whose trunks were badly cankered by southern fusiform rust. It was applied with little regard to spatial arrangement of the trees left.

The heavy thinnings were designed, regardless of the volume of wood that might be salvaged, to leave prescribed numbers of trees per acre for further growth, and to leave more at the closer spacings, where diameter growth had been poorer, than at the wider spacings. In slash pine the numbers left ranged from 432 per acre in the 8 by 8 spacing to 630 in the 5 by 5; at the same spacings in loblolly the numbers ranged from 368 to 704. Like the light thinning, heavy thinning was mainly from below, but with less care to remove the smallest trees and more to salvage rust-cankered stems and to insure good spatial arrangement of the remaining stand.

Further thinnings at 5-year or even shorter intervals were planned, but conditions during and shortly after World War II precluded doing the work within reasonable time. Thus the study was reduced to the simple terms of three replications apiece of a single heavy thinning, a single light thinning, and the unthinned check in each spacing of each species.

Analysis of the data taken a year or less before thinning showed that, in survival up to the time of thinning and in numbers of trees per acre, volumes of pulpwood per acre, and mean d.b.h. of all trees before thinning, the mean values of the sets of plots to which the three experimental treatments were assigned were satisfactorily uniform within each spacing of each species. Analysis of variance showed specifically that, up to the time of thinning, survival within spacings had not varied significantly (table 1, page 5).

The mean numbers of trees left after thinning are given, separately by species × spacing × thinning-treatment combinations, in table 2, page 6. Differences between light and heavy thinnings generally increased with increasing closeness of spacing, and were greater in slash than in loblolly pine.

Mean volumes of pulpwood left after thinning ranged from a minimum of 10.3 to a maximum of 27.0 cords (table 3, page 7). They were consistently higher on the unthinned check plots than on the thinned plots,

and (with one trifling exception) higher on the lightly thinned than on the heavily thinned plots. Despite great variability among replications of some of the thinning treatments, mean volumes left per acre varied significantly in the slash at 5 by 5 spacing and in all three spacings of loblolly pine. Thinning, in other words, resulted in immediate significant differences among previously uniform volumes.

The volumes of merchantable pulpwood removed in thinnings ranged from 2.6 to 8.8 cords per acre (table 3). They varied greatly with species, spacings, and thinning treatments. In the light thinnings at the closer spacings, volumes salvaged in thinning were reduced by concentration of cutting upon the smallest trees, many of which, at these spacings, were below pulpwood size. Except in the slash pine at 8 by 8 feet, the heavy thinnings yielded 2.0 to 2.5 times as much merchantable wood as the light ones, but at this spacing in slash most of the smaller trees were merchantable and hence were included in the pulpwood yield from the light thinning.

Mean diameters of trees left after thinning ranged from 4.3 inches in the unthinned checks of both slash and loblolly at 5- by 5-foot spacing to 6.0 inches in the lightly thinned loblolly at 8 by 8. Diameters in the unthinned checks varied directly with spacings—in both species from 4.3 inches at 5 by 5 feet to 5.4 at 8 by 8. Thinnings of both intensities, but especially the heavy ones in slash and the light ones in loblolly, directly increased mean diameters; in the slash at 5 by 5 and in the loblolly at 6 by 6 the increases were significant at the 0.05 level.

The values summarized thus far indicate the conditions of the plots up to and immediately after the thinnings. They show the effects of spacings up to the time of thinning and on the thinnings themselves and the initial effects of the thinnings on the stands left for further growth. They set a stage, so to speak, on which the later effects of both thinnings and spacings might become manifest.

Major Results

Survival.—Thinnings appreciably affected survivals through the latter half of the rotation. At final measurement the mean survival of the trees retained at the time of thinning was invariably higher on the thinned plots than on the unthinned check plots of the same species and spacing. In slash pine it averaged consistently highest on the heavily thinned plots; in loblolly, on the lightly thinned. Survival differences among thinning treatments were significant in the slash at 5- by 5-foot spacing and in the loblolly at 6 by 6 and 8 by 8 (table 1).

Spacings also affected the ultimate survival of trees left after thinning. Although lack of replication forestalled tests of significance, there was a marked tendency, thinning treatment by thinning treatment, for survival to vary directly with initial width of spacing (table 1.)

Number of trees per acre.—Thinning had reduced the mean numbers of trees on the treated plots far below those on the check plots, and in

Table 1.—*Mean survivals of trees planted and of trees left after thinning*

Spacing (feet)	Till time of thinning [1] [2]			At final measurement [1] [3]		
	Heavy	Light	Check	Heavy	Light	Check
	.... *Percent* [4]			.... *Percent* [5]		
			SLASH PINE			
8 by 8	89.8a	93.5a	89.5a	81.8a	79.0a	74.8a
6 by 6	90.3a	85.3a	89.0a	79.0a	77.0a	62.7a
5 by 5	85.8a	82.8a	85.5a	83.2a	71.0b	53.7c
			LOBLOLLY PINE			
8 by 8	91.2a	89.9a	92.1a	74.6ab	86.4a	64.1b
6 by 6	87.5a	89.5a	86.1a	60.7a	71.8b	52.8c
5 by 5	76.2a	77.1a	71.6a	62.2a	65.9a	46.3a

[1] Means within any one species and spacing, if followed by the same letter, do not differ at the 0.05 level of significance.
[2] At age 15 years in slash pine and 19 in loblolly.
[3] At age 30 years in slash pine and 34 in loblolly.
[4] Based on number of spaces planted.
[5] Based on live trees left after thinning.

two of the three spacings of each species had reduced the numbers on the heavily thinned plots below those on the lightly thinned. Except at the 8- by 8-foot spacings, the differences among treatments were significant. By final measurement, however, severe mortality on the check plots, and erratic mortality on the thinned plots at the closer spacings, had somewhat obscured this pattern. The thinned plots still averaged consistently fewer trees per acre than the corresponding check plots, but now fewer than half of the differences were significant (table 2).

Thinning treatment by thinning treatment within species, the closest spacings had conspicuously the most trees per acre at final measurement and the widest had the fewest, just as they had had when first planted (table 2).

Mean diameter breast high.—In slash pine, mean diameters at final measurement ranged from 6.5 inches in the unthinned check at 5 by 5 spacings to 8.3 inches in the lightly thinned 8 by 8. In loblolly, they ranged from 7.1 inches in the unthinned check at 5 by 5 to 8.3 inches in the lightly thinned 8 by 8. In no one spacing of either species, however, did final diameters vary significantly. The significance of the differences observed immediately after thinning, and attributable to thinning treatments, had been transitory.

Final diameters were, nevertheless, consistently smallest on the unthinned check plots. Further, there was a fairly strong trend, thinning

Table 2.—*Mean numbers of living trees per acre immediately after thinning and at final measurement*

Spacing (feet)	Immediately after thinning [1]			At final measurement [1]		
	Heavy	Light	Check	Heavy	Light	Check
			SLASH PINE			
8 by 8	432a	428a	569a	354a	337a	425a
6 by 6	526a	679b	1,004c	416a	523ab	626b
5 by 5	630a	954b	1,342c	524a	674b	717b
			LOBLOLLY PINE			
8 by 8	368a	386a	549a	274a	334a	352a
6 by 6	665a	619a	958b	405a	442a	506a
5 by 5	704a	749a	1,143b	438a	493ab	524b

[1] Means within any one species and spacing, if followed by the same letter, do not differ at the 0.05 level of significance.

treatment by thinning treatment, for final diameters to vary directly with spacing. Such a trend is important in two ways. Its onset affects the age at which commercial thinning first becomes feasible, and its continuation after thinning affects the rotation age for any desired final product and, possibly, the cost of final cutting.

Live pulpwood at final measurement.—In contrast to the often significantly different volumes left after thinning, the mean live pulpwood volumes at final measurement did not vary significantly within any one spacing of either species (table 3).

Thinning treatment by thinning treatment, final live volumes of loblolly pine varied inversely with width of spacing. In the slash pine unthinned checks the reverse was true; the final live pulpwood volumes varied directly with width of spacing. Under both intensities of thinning in slash pine, almost certainly because of confounding of unreplicated spacing with site, final live volumes were greatest at 5 by 5 spacing and least at 6 by 6 (table 3).

The mean increases in volume between thinning and final measurement, expressed as percentages of the mean pulpwood volumes left after thinning, varied tremendously. In slash pine they ranged from 85 percent in the unthinned checks at 5- by 5-foot spacing to 235 percent in the lightly thinned 8 by 8. In loblolly they ranged from 145 percent in the unthinned checks at 5 by 5 to 223 in the heavily thinned 8 by 8.

Because of wide variations among the replications of like treatments, the increases did not appear to vary significantly among thinning treatments within any one spacing of either species. They did tend strong-

Table 3.—*Mean pulpwood volumes at time of thinning and at final measurement*

Spacing (feet)	Left after thinning [1] [2]			Salvaged in thinning [3]			Alive at final measurement [1]			Total merchantable volume produced [1] [3]		
	Heavy	Light	Check	Heavy	Light	Check	Heavy	Light	Check	Heavy	Light	Check
	Cords											
	SLASH PINE											
8 by 8	13.8a	13.6a	18.6a	3.3	3.1	0.0	44.6a	45.6a	52.4a	47.9a	48.7a	52.4a
6 by 6	14.4a	17.2a	23.7a	8.4	4.3	.0	40.8a	44.1a	51.2a	49.2a	48.4a	51.2a
5 by 5	18.9a	23.7b	27.0c	8.2	4.3	.0	46.0a	48.1a	49.9a	54.2a	52.4a	49.9a
	LOBLOLLY PINE											
8 by 8	10.3a	14.0b	16.6c	5.7	2.7	0.0	33.1a	40.7a	39.9a	38.8a	43.4a	39.9a
6 by 6	12.3a	15.9b	17.6c	5.8	2.6	.0	36.5a	43.0a	45.0a	42.3a	45.6a	45.0a
5 by 5	14.2a	18.0b	19.3b	8.8	3.4	.0	39.6a	44.1a	47.6a	48.4a	47.5a	47.6a

[1] Means within any one species and spacing, if followed by the same letter, do not differ at the 0.05 level of significance.

[2] Values scant by the amounts of wood put on between March and June 1940 by slash pines left after thinning, and during 1941 by loblollies left after thinning.

[3] Values scant by the amounts of wood put on between March and June 1940 by slash pines salvaged in thinning, and during 1941 by loblollies salvaged in thinning.

ly, however, to vary directly both with width of initial spacing and with intensity of thinnings with spacings. In general terms, both wide spacing and heavy thinning represented smaller investments in wood capital during the period between thinning and final measurement, and higher rates of return (in the form of volume growth) on these investments.

Total pulpwood yield at final measurement.—When the mean volumes of pulpwood salvages in thinning were added to the mean volumes alive at final measurement, the totals did not differ significantly among thinning treatments (including the unthinned checks) at any spacing of either species. There was, in fact, no discernible pattern of responses to thinning except that in both species the minimum total yield was from heavily thinned 8- by 8-foot spacing and the maximum was from the heavily thinned 5 by 5 (table 3). As the main purpose of the thinnings had been to increase yields by salvaging trees that would otherwise die before rotation age and by stimulating the growth of trees retained after thinning, the thinnings reported here must be judged ineffective.

Thinning treatment by thinning treatment, mean total pulpwood yields tended strongly to vary inversely with width of initial spacing, except that in the unthinned slash pine checks they varied directly with spacing (table 3). This reverse trend in the slash pine checks, coupled with the final survivals and final lives volumes shown in tables 1 and 3, suggests that slash pine may be less tolerant of crowding than loblolly pine.

Minor Results

Mean total height of all trees.—In slash pine, mean total heights at final measurement ranged from 57 feet in the unthinned check at 5 by 5 spacing to 63 in the lightly thinned 8 by 8; in loblolly, from 58 in the heavily thinned 6 by 6 to 63 in the lightly thinned 8 by 8. Thinning had no significant effect on final heights. Thinning treatment by thinning treatment, final heights in slash pine varied directly with width of spacing, but in loblolly, presumably because of confounding of spacing with site, they were least at 6 by 6 and approximately equal at 5 by 5 and 8 by 8.

Degree of dominance.—In slash pine at final measurement, mean percentages of dominant plus codominant trees ranged from 38 in the unthinned checks at 5 by 5 spacing to 72 in the lightly thinned 8 by 8. In loblolly they ranged from 47 in the unthinned checks at 5 by 5 to 73 in the heavily thinned 8 by 8. Spacing by spacing, with one minor exception, percentage of dominance was lowest in the unthinned checks. At 5 by 5 spacing of each species, the percentage in the checks was significantly lower than that in the thinned plots. Except for the differences among survival percents and numbers of trees per acre (tables 1 and 2), these differences in degree of dominance were the only significant variations that, at final measurement, were attributable to thinning treatments.

Under all three thinning treatments in slash pine, and on the unthinned check plots in loblolly pine, percentage of dominance varied directly with width of spacing.

Degree of infection with fusiform rust.—In slash pine, percentages of trunk infection at final measurement ranged from 21 to 40; of trunk infection plus infection in brances only, from 31 to 49. The corresponding values for loblolly were 6 to 19 and 7 to 20. Although infection was clearly greater in slash pine, both incidence of infection and survival of infected trees appeared to have been random with respect to both spacings and thinnings. Certainly there was no evidence that close spacing had reduced the incidence of rust or that purposeful removal of heavily infested trees in thinning had decreased the extent of infection at the end of a feasible pulpwood rotation.

Discussion and Conclusions

The final measurements made at ages 30 (in slash pine) and 34 (in loblolly) substantiate many results observed or predicted in previous articles on tests of Southern pine thinnings and spacings (*1, 2, 3, 4, 5, 6, 8, 9, 10, 11*). Specifically, the present study confirms: 1.—The adverse effect of close spacing upon diameter growth but its generally favorable effect upon pulpwood yield per acre. 2.—The frequently very similar effects, upon growth and yield, of distinctly different thinning treatments. 3.—The not uncommon failure of thinning to increase significantly the total pulpwood production per acre but its fairly consistent tendency to result in larger diameters at final measurement. 4.—The failure of spacing to affect appreciably the extent of rust infection at final measurement.

Several of the articles cited (*3, 4, 9, 10, 11*) indicate that some or all of the thinning treatments they describe were financially advantageous. Such indications, especially those based on measurements made at only half to two-thirds of rotation age, are highly speculative. They involve assumptions (concerning costs, interest rates, markets, and future growth) that are not pertinent to the present study. The simplest and most realistic economic evaluation of the spacing and thinning experiments reported here would seem to be one made in the combined light of the general setting of the plantations, certain principles regarding planting and thinning costs, and the yields obtained from the experimental plots.

In the decades since these plots were established, woods labor has become increasingly hard to obtain, and labor costs have risen greatly, with little indication of stabilization even at present levels. The trend in the pulp industry is toward mechanization of woods operations; row thinning lends itself better to mechanization than does the removal of individually marked trees; and mechanization of either type of thinning would be facilitated by wide spacing. Planting continues, but, spacing by spacing, at far higher costs than those prevalent when the experimental plantations were established.

As numbers of trees planted per acre decrease, costs of planting stock per acre decrease in direct proportion. Corresponding decreases in costs of labor for planting are relatively greater because the wider spacings involve not only fewer trees to plant but also fewer traverses of each acre. The cost per cord of cutting pulpwood decreases with increasing mean diameter of the trees cut. In marking thinnings, costs are least in the simplest systems. The cost of the removing pulpwood in thinnings would ordinarily be reduced by mechanization and, whether the work was mechanized or done by hand, probably would be lowest in one or another form of row thinning.

In the light of these local circumstances and of the general principles governing costs, the least intensive and most intensive treatments tested in the Bogalusa plantations can be compared in terms of the results observed at final measurement.

In each species the least intensive treatment was planting at 8- by 8-foot spacing without subsequent thinning. The most intensive was planting at 5 by 5, with a single commercial thinning. As severity of thinning did not significantly affect results within spacings, both the diameters and the total yields resulting from light and heavy thinnings are averaged in the following examples.

In slash pine at age 30 years, the mean total pulpwood yield of the unthinned check plots at 8 by 8 spacing was 52.4 cords per acre. That of the thinned plots at 5 by 5 was 53.3 cords per acre, or 1.7 percent higher. Only 636 trees per acre, however, had been planted in the 8 by 8 spacing, as against 1,556 per acre in the 5 by 5. The 1.7-percent increase in yield, therefore, was obtained at a 145-percent greater cost of establishment. At age 30, moreover, the mean diameter on the unthinned check plots at 8 by 8 was 7.9 inches, as against a mean of 6.9 inches on the thinned plots at 5 by 5. The difference would have made the pulpwood on the 8 by 8 check plots appreciably cheaper to cut.

In loblolly pine at age 34 years the unthinned check plots at 8 by 8 had a mean total pulpwood yield of 39.9 cords per acre; the thinned plots at 5 by 5 had a mean total yield of 48.0 cords, or 20.3 percent more. This increase, however, was associated with the planting of 1,624 trees per acre at 5 by 5 spacing, at an establishment cost 172 percent greater than that of the 598 trees planted per acre at 8 by 8. Further, the mean diameter of the trees on the unthinned check plots at 8 by 8 was 8.1 inches, as against a mean of 7.2 inches on the thinned plots at 5 by 5.

In both species the cost-and-return relationships for 6 by 6 spacing were intermediate between those of the 8 by 8 and the 5 by 5.

To sum up, the thinnings described here had no significant effects on final yields or on the degree of rust infection at final measurement. In terms both of financial returns, however, and of total requirements for labor, 8- by 8-foot spacing without subsequent thinning appeared clearly preferable to planting at closer spacings, either with or without thinning.

Literature Cited

1. Bennett, F. A.
   1956. Growth of slash pine plantations on the George Walton Experimental Forest. USDA Forest Serv. Southeast. Forest Exp. Sta., Sta. Pap. 66, 21 pp.

2. Bennett, F. A., McGee, C. E., and Clutter, J. L.
   1959. Yield of old-field slash pine plantations. USDA Forest Serv. Southeast. Forest Exp. Sta., Sta. Pap. 107, 19 pp.

3. Keister, T. D.
   1967. Effect of thinning on diameter growth of the largest trees in a slash pine plantation. La. State Univ. Forest. Note 71, 3 pp.

4. Keister, T. D., Crow, A. B., and Burns, P. Y.
   1968. Results of a test of classical thinning methods in a slash pine plantation. J. Forest. 66: 409-411.

5. Kulow, D. L., and Schumacher, F. X.
   1968. Slash pine growth in Florida, J. Forest. 66:72.

6. Little, S., Mohr, J. J., and Mook, P. V.
   1968. Ten-year effects from row thinnings in loblolly pine plantations of eastern Maryland. USDA Forest Serv. Res. Note NE-77, 8 pp. Northeast. Forest Exp. Sta., Upper Darby, Pa.

7. Office of Forest Experiment Stations, Forest Service, and Cooperating Agencies.
   1929. Volume, yield, and stand tables for second-growth southern pines. USDA Misc. Pub. 50, 202 pp.

8. Shoulders, E.
   1967. Growth of slash and longleaf pines after cultivation, fertilization, and thinning. USDA Forest Serv. Res. Note SO-59, 3 pp. South. Forest Exp. Sta., New Orleans, La.

9. Smith, L. F.
   1967. Effects of spacing and site on the growth and yield of planted slash pine. USDA Forest Serv. Res. Note SO-63, 4 pp. South. Forest Exp. Sta., New Orleans, La.

10. Ware, L. M., and Stahelin, R.
    1948. Growth of southern pine plantations at various spacings. J. Forest. 46:267-274.

11. Williston, H. L.
1967. Thinning desirable in loblolly pine plantations in west Tennessee. USDA Forest Serv. Res. Note SO-61, 7 pp. South. Forest Exp. Sta., New Orleans, La.

Fleshy Fungi Commonly Eaten By Southern Wildlife

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Fleshy Fungi Commonly Eaten By Southern Wildlife

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Southern Forest Experiment Station
Forest Service
U. S. Department of Agriculture

1969

CAUTION:

Many species of mushrooms that are deadly to man are apparently harmless to wildlife. Animal use does not indicate edibility for humans.

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Fleshy Fungi Commonly Eaten By Southern Wildlife

Howard A. Miller [1] **and Lowell K. Halls** [2]

Mushrooms appear to be an important component of the diet for wildlife in the South. They are eaten by deer, small mammals such as squirrels and other rodents, birds, turtles, and numerous species of insects.

In winter, when the food needs of wildlife are usually critical, mushrooms are particularly important, especially to white-tailed deer. During this period the highly nutritious mushrooms help to compensate for nutrient deficiencies in native forage.

At the Atomic Energy Commission's Savannah River Project in South Carolina, David F. Urbston of the USDA Forest Service reported that deer ate mushrooms at all seasons (unpublished data). In an analysis of 100 deer stomachs, he found that 95 percent contained mushrooms or other fungi, varying in volume from a trace to 83 percent. Strode *(21)* lists mushrooms as the most important food for deer on the Ocala National Forest in Florida. He found that 79 percent of deer stomachs examined contained mushrooms; percent by volume was 24. In Missouri, 50 out of 270 deer stomachs contained fungi *(14)*.

While at the Southeastern Forest Experiment Station, Charles Cushwa and colleagues collected stomach samples from deer in the major physiographic provinces of the Southeast. Percent of stomachs containing mushrooms ranged from 10 to 100, depending on province and season; content by volume ranged from 1 to 27 percent (unpublished). Use was generally highest in summer.

Game birds such as grouse, turkeys, and quail feed heavily on mushrooms. Grouse and turkeys, which are strong scratchers, easily uncover mushrooms hidden by pine needles or hardwood leaves. Broken ends and threads of mycelia that have been pulled up indicate the presence of fungi and use by birds. Quail, being weak scratchers, often feed on pieces of mushroom left by rodents.

Among rodents that eat mushrooms are squirrels and white-footed and deer mice. The western gray squirrel feeds heavily on subterranean fungi, such as false truffles. The eastern gray squirrel favors above-ground mushrooms. In Ohio, mushrooms ranked high in the gray squirrel diet *(18)*. In Virginia, fleshy fungi constituted 26 percent of the fall diet and 16 percent of the winter diet of gray squirrels *(5)*.

The fruiting bodies of mushrooms, which are often heavily infested by insects, are also a source of food for birds. Robins and bluejays, for example, frequently tear mushrooms apart in search of larvae.

Four species of mushrooms are preferred far more than others. In order of preference they are peppery lactarius *(Lactarius piperatus)*, little red russula *(Russula roseipes)*, honey mushroom *(Armillaria mellea)*, and granulated bolete *(Suillus granulatus)*.

Purpose of this guide is to aid in identification of mushrooms commonly eaten by wildlife in the southern forests extending from Texas to Virginia. In addition, the aim is to stimulate interest in research on mushrooms as wildlife food and on their ecology and growth.

The fungi described here occur commonly in one or more physiographic provinces of the South. They are known to be eaten by one or more species of wildlife. Their fruiting bodies are large enough (i.e., at least 2 inches in diameter) to provide a substantial segment of the diet for larger birds and mammals. Only mushrooms that meet these requirements according to present knowledge are included here. For those interested in additional information, a list of comprehensive manuals is provided.

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NUTRITIVE VALUE

Fresh fleshy fungi have high moisture contents, usually between 75 and 90 percent. Thus, rather large volumes have to be consumed to provide adequate protein and phosphorus. A protein content of about 30 percent of dry weight has been reported for a typical *Morchella (17).* Crude protein content averaged 17 percent (dry weight basis) for several specimens of *Hygrophorus, Armillaria, Russula, Clitocybe, Tricholoma, Pholiota,* and *Amanita* collected during late autumn in Georgia; the range was from 12 to 27 percent. Phosphorus averaged 0.40 percent, ranging from 0.20 to 0.58 percent.

In east Texas, specimens of *Hygrophorus* and *Amanita* collected during early winter averaged 23 percent crude protein and 0.55 percent phosphorus. The same samples averaged only 12 percent in crude fiber content, an indication that they are readily digestible by ruminants such as cattle and deer.

Samples of *Morchella, Rhizopogon, Cortinarius, Amanita, Clitocybe,* and *Lactarius* collected in May averaged 30 percent crude protein, 17 percent crude fiber, and 0.68 percent phosphorus.

HABITAT REQUIREMENTS

Fleshy fungi are particularly abundant in the litter on the forest floor. Some fungi are found only in association with conifers and others with hardwoods. Some seem to be dependent upon a single tree species. A few are parasitic on other mushrooms. Certain fungi are especially numerous in soils where organic content is high. A few live mainly on the slash left after logging of hardwoods. Many establish a mycorrhizal association with tree roots.

The mushroom population in the forest changes with the seasons. *Morchella,* or morels, usually appear in the coolness of early spring, *Boletus* in the summer, *Cortinarius* in autumn, *Hygrophorus* in early winter, and *Collybia* during winter *(15).*

The greatest number of species are usually found where the forest floor is covered with sufficient humus, dead leaves, thick moss, or other debris to hold moisture. Mycelia can live for many years, and mushrooms are often found in about the same spot each year. During a drought, fruiting bodies are seldom seen, an a long rainy spell may be necessary before the appear above ground. Except where rotte logs and woods retain moisture, a single heav rain or even a number of scattered showe may not be sufficient to induce growth *(12*

Certain conditions of temperature and hu midity must be present even when soil moi ture is ample. Commercial mushrooms grow best between 50° and 60°F., but in the wil there is a wider tolerance *(15).* If showe occur frequently during warm weather, a larg number of species can be found fruiting simu taneously in a small area *(20).*

Since mushrooms lack chlorophyll and ge their food from organic matter, direct sunligh is not necessary for growth. The mycelium capable of fruiting even under dense shad given the proper temperature and moistur This characteristic will become increasingl important in management of game habitat un der dense pine stands grown on short rotation

Any forest management practice that result in disturbance to the soil or an accumulatio of derbis and organic material will usuall affect the mushroom population. Species o mushrooms that live on slash and downed tree should increase for several years followin logging. Later, as the debris breaks down additions to the duff provide a medium o which a large number of mushrooms of othe species live.

Burning, an important management tech nique, often causes certain fungi to fruit fo a few years, after which they are not see until the next burn. On six burned plots o loblolly and shortleaf pines *(Pinus taeda, P echinata),* the senior author observed that fir apparently induced heavy fruiting of *Suillu granulatus, Russula delica, R. variata, Arm illaria ventricosa,* and *Hygrophorus tennessee sis.* On the other hand, where fire destroys substantial proportion of the litter, the numbe and kinds of fleshy fungi will probably declin

In southern forests where upland hardwood have been converted to pines, certain mush rooms that were scarce or absent among th hardwoods become abundant. Species such a *Amanita verna, A. chlorinosma,* and *Lactariu piperatus* tolerate the high density of your stands and the lack of hardwood litter an debris.

Agaricaceae

Members of the family Agaricaceae are parasol-shaped fungi bearing gills under the cap. They are sometimes known as the true mushrooms. The agarics may be grouped according to the color of their spore masses. Wildlife apparently prefer those in the white, pink, purple-brown, and yellow-brown groups. No use of species with black spores has been observed, probably because as the fungi mature the caps and gills liquify through a process of autodigestion.

Species described here are arranged alphabetically by genera within spore-color groups.

Amanita

Amanitas are eaten by deer, squirrel, turkey, grouse, and other birds and mammals. Most of them are deadly to humans, however.

These beautiful mushrooms range in color from pure white to brilliant red and orange. The spores are white and the gills are free or only slightly attached to the stem. The outer veil, when broken, becomes the volva or cup at the base of the stem. The inner veil, when broken, becomes the ring on the stem.

Species described here are common in southern pine-hardwood forests.

Browning amanita

Browning Amanita

Amanita brunnescens

CAP 1½ to 4 inches wide; conical, becoming flat convex with small umbo; tan to gray-brown, smoky; nauseous odor

GILLS white; close; medium broad

STEM 2 to 5 inches long; tapering upward and often splitting up and down

RING on upper portion of stem

VOLVA a shallow cup, if at all

Occurs from June through August.

Caesar's Mushroom

Amanita caesarea

CAP 2 to 5 inches wide; conical, becoming convex to flat; red to orange; scales rarely found on mature specimens

GILLS white or slightly yellow; close and medium broad

STEM 4 to 7 inches long; yellowish

RING yellowish

VOLVA deep, well-formed white cup

This colorful mushroom is found from July through August.

Caesar's mushroom—mature and immature

Chlorine amanita

Chlorine amanita—sectioned

Chlorine Amanita

Amanita chlorinosma

CAP 3 to 10 inches wide; conical; whitish or pale cream; has odor of strong lime or old ham

GILLS white to creamy; close

STEM 4 to 10 inches long; bulbous at ground

RING fragile, soon disappears

VOLVA mealy powder on base of stem

Warty scales on the central portion become soft and powdery and often fall from the cap and stem fruiting bodies occur from July to November.

Tawny Amanita

Amanita fulva

CAP 1 to 4 inches wide; conical; tawny to gray or pale orange to buff, with conspicuously striate margin

GILLS white, close and narrow

STEM 3 to 5 inches long; whitish above and dull yellow below

RING not evident

VOLVA white; deeply cup-like

Occurs solitarily and scattered June to August.

Tawny amanita

Fly Mushroom

Amanita muscaria

CAP 4 to 6 inches wide; egg-shaped when young; convex to flat and often slightly concave when mature; surface pale yellow to orange, sometimes reddish, often with white or pale yellow scales in concentric rings

GILLS white, turning yellow; close and broad

STEM 4 to 6 inches long; enlarged at base and tapering upward; yellowish white

RING fragile, often hanging from stem or cap edge

VOLVA scales or broken ridges encircling lower stem and bulb

Found from June to October.

Fly amanita

Fly amanita

Solitary Amanita

Amanita solitaria

CAP 3 to 5 inches wide; first conical, later flat; surface white or nearly so with brownish warts

GILLS white to yellowish; close

STEM 4 to 8 inches long; scaly and bulbous at ground line

RING white; at first attached to stem; remnants of veil often persist on gills

VOLVA scales on base; no well-formed cup

Occurs singly, June through August.

Solitary amanita

Solitary amanita—veil remnants

Destroying Angel

Amanita verna

CAP 2 to 5 inches wide; convex to flat; white

GILLS faintly serrate in older specimens

STEM 4 to 7 inches long; white; bulbous a base

RING white, often hanging from uppe portion of stem

VOLVA cup-like, often in soil

Usually grows solitarily or i small groups, June to August; dead ly to humans.

Destroying angel

Armillaria

Species in this genus have white spores, and the gills are attached to the stalk. A ring occurs on the stem, but it is often inconspicuous and short-lived. In contrast to amanitas, armillarias have no volva. The stem is continuous with the cap and does not separate readily. Armillarias differ from lepiotas, the other white-spored mushroom with a ring, by their attached gills; in lepiotas the gills are free. Armillarias occur in pine and pine-mixed hardwoods in the mountains, Piedmont, and upper Coastal Plain.

Booted Armillaria

Armillaria caligata

CAP 2 to 6 inches wide; flat or funnel-shaped at maturity; reddish-brown scales tinged with purple

GILLS white to grayish, turning brown with age

STEM 2 to 3 inches long; brownish and scaly below, white and smooth a bove

RING flaring and conspicuous

The lower portion and light up per part resemble a boot; common in autumn; often associated with huckleberry thickets.

Booted armillaria—variant

Honey Mushroom

Armillaria mellea

CAP 2 to 5 inches wide; convex to flat when mature; honey-colored or brown, usually scaly; surface of young plants sticky

GILLS decurrent; pale yellow to white, frequently brownish when mature

STEM 4 to 10 inches long; tapering downward and scaly to pointed "root"

RING at first stands out like collar, later collapses and may disappear

This common mushroom grows abundantly in large clusters about stumps of deciduous trees; it often produces black strands of fungal filament, under the bark, that resembles shoestrings; found mainly in September and October.

Honey mushroom—squirrels and turkeys feed heavily on this species.

Swollen-Stalked Armillaria

Armillaria ventricosa

CAP 4 to 12 inches wide; depressed in center when young, flat or funnel-shaped when mature; shining and smooth; whitish or silver-gray

GILLS decurrent; narrow and white

STEM 2 to 6 inches long; stout; tapering rapidly to point

RING flaring and prominent

This species is important to deer in late fall and winter.

Swollen-stalked armillaria

Lepiota

Most *Lepiota* species have white spores though some have cream-colored or green spores. All have a ring on the stem, which separates readily from the cap. The gills are free. Lepiotas resemble amanitas except that they do not have a cup. They grow on the ground, on debris, or on rotten wood. Wildlife do not feed heavily on them, probably because they occur along with large and succulent species of *Lactarius,* which may be more attractive. Three species, however, are locally common enough to be considered valuable for wildlife.

Green-Gilled Mushroom

Lepiota molybdites

CAP 3 to 8 inches wide; buff with pale brownish scales

GILLS becoming dull green with maturity; spores green in mass

STEM 3 to 8 inches long; tapering toward bulbous base

RING whitish; becomes movable

Found mainly in grasslands, July to early fall.

Green-gilled mushroom—immature group

Smooth Lepiota

Lepiota naucina

CAP 2 to 4 inches wide; oval when young, later convex to almost flat; surface smooth or faintly cracked; white with central portion frequently smoky

GILLS close and white when young, later turning pinkish and finally pale brown; edge serrate; spores white

STEM 2 to 5 inches long; tapering upward from bulbous base; white and hollow when mature

RING prominent, sticking out from stem

Grows on the ground in grasslands and open hardwood types, June to October.

Smooth lepiota

Parasol Mushroom

Lepiota procera

CAP 2 to 6 inches wide; reddish brown with conspicuous concentric brownish scales

GILLS close; white, then pinkish or brownish; spores white

STEM 6 to 9 inches long with brownish scales and bulbous base

RING movable

A grassland species, July to early fall.

Russula

The species number in the hundreds. Many are yet to be described. They are widely distributed and occur in all major cover types. Judging from the use by wildlife, they are quite palatable.

Russula species have no ring or cup. The stem and cap are continuous. Cap colors range from dingy white through all the colors of the rainbow. The spore mass is basically white or pale cream, but in several species it is bright yellow. The gills are brittle and easily break into small pieces.

This genus resembles *Lactarius* in many ways. General shape and growth habits are similar. During wet weather both may exude droplets of liquid from their gills and the edges

of their caps. Russulas will not, however, exude a milky substance from the flesh of the cap, when broken.

Typical russula

Scarlet Russula

Russula borealis

CAP 3 to 7 inches wide; spherical when young, later flat or depressed in the center; dry and not sticky, easily peeled from surface; white flesh tinged red beneath cuticle; scarlet or blood-red in center, fading toward edge

GILLS short, decurrent; spore mass yellow

STEM 3 to 5 inches long; uniform in diameter; often white, spotted or tinged with red

Occurs usually in groups of two to four, August to October.

Scarlet russula sectioned

Encrusted Russula

Russula crustosa

CAP 2 to 5 inches wide; depressed in center; margin recurved when young, later upraised and striate; surface sticky and greenish, appearing crusted and scaly

GILLS white, later buff; spores whitish

STEM 2 to 4 inches long; white; thick at tip and tapering toward base

Found in summer.

Zoned-Stem Russula

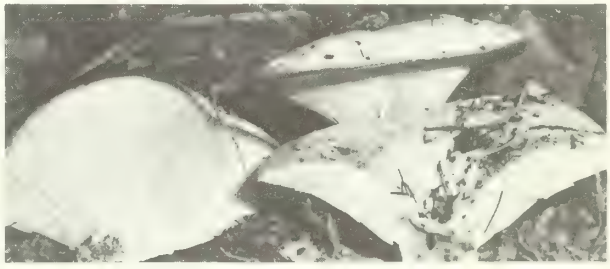
Russula delica

CAP 5 to 10 inches wide; at first with central depression; margin upraised later so cap has broad funnel shape; smooth but sometimes faintly hairy; surface dull white with rusty brown patches, yellowish stains, and concentric rings

GILLS short decurrent; white; short and long gills alternating; spore mass creamy white with faint pinkish cast

STEM ½ to 1½ inches long; cylindrical; usually with blue-green ring at top

Fruits from August through December.



Zoned-stem russula—sectioned

Fetid Russula

Russula foetens

CAP 2 to 5 inches wide; sticky; at first spherical, later flat or nearly so with tan to pale brown, coarsely striate margin

GILLS pale yellow; short decurrent or attached; usually exudes drops of

Fetid russula

liquid from edges when fresh; spores white

STEM 2 to 4 inches long; white or pale brown where bruised; quickly hollowed out by insect larvae; putrid odor when mature

Occurs from July through September.

Little Red Russula

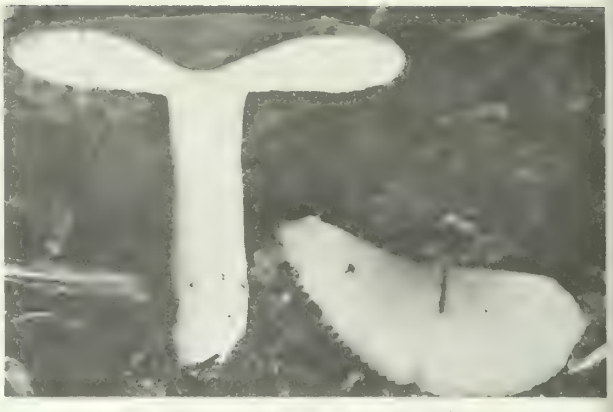
Russula roseipes

CAP 1½ to 3 inches wide; convex; flat or slightly depressed in center; sticky when young; margin prominently striate; cuticle easily peels off; surface bright red and may be slightly yellow in center

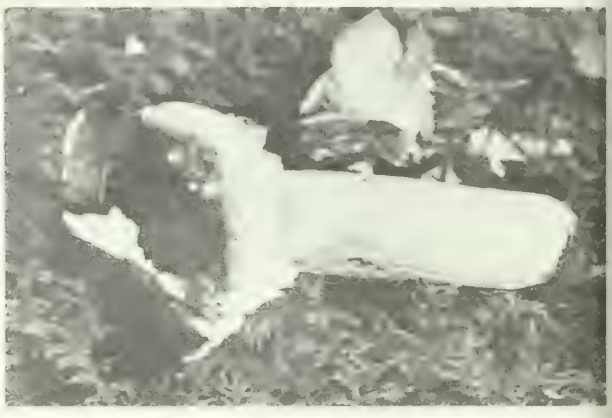
GILLS free or slightly attached; white when young, turning yellow with maturity; spores yellow

STEM 1 to 2 inches long; cylindrical or slightly tapered upward; white or pale red; spongy

Usually found scattered under conifers but sometimes occurs in pine-hardwood types, August to October.



Little red russula—sectioned



Wildlife apparently prefer little red russula more than most species.

Variable Russula

Russula variata

CAP 2 to 4 inches wide; pinkish to deep wine and lavender; convex to flat, often with depression in center

GILLS white; finely branched toward outside

Variable russula

STEM 2 to 4 inches long, white, moderately stout

Found in pine types in the Coastal Plain and among hardwoods in the mountains; fruits from May to September and is responsive to fire.

Green Russula

Russula virescens

CAP 2 to 6 inches wide; flat to slightly depressed in center; green to grayish-green or olive; at maturity solid color breaks, showing white flesh beneath

GILLS white, free; spores white

STEM 1 to 3 inches long; thick and often tapered near base or on both ends

Grows singly from June through October.

Green russula

Lactarius

Members of this genus are among the largest and showiest mushrooms in the woods. They are highly attractive to insects, rodents, and deer. An untouched, mature specimen is rarely found.

Species range from about 4 inches in diameter to as large as a dinner plate. They have white spores and attached or decurrent gills. Cap and stem are continuous. The cap is more often depressed to funnel-shaped. The single most distinguishing character is the presence of white or colored juice when the cap is broken. In wet weather, droplets often ooze from the gills. Droplets are not visibly exuded from old dry specimens; a low-power lens may be required to distinguish their presence.

The genus is well distributed in the mountains, the Piedmont, and Coastal Plains, as well as on flood plains of the major rivers. It is mostly terrestial, sometimes on much decayed wood. *Lactarius* species often occur in large numbers in the open woods of higher ground.

Blue Lactarius

Lactarius indigo

CAP 2 to 6 inches wide; convex with central depression when young, becoming broad, funnel-shaped at maturity; concentric bands

GILLS blue, at times pale green; decurrent and occasionally forked

Blue lactarius

STEM 1 to 3 inches long; stout; blue

Grows solitarily, August and September; blue juice exuding from cap and gills.

Peppery Lactarius

Lactarius piperatus

CAP 4 to 12 inches wide; margin incurved at first, center later depressed to funnel-shaped; surface white, dry, smooth

Peppery lactarius

GILLS white, decurrent, crowded, and forked

STEM 1 to 3 inches long; white and stout, often tapering downward; may be finely pubescent

Grows in hardwood stands and occasionally in pines, August and September; normally in groups of four to eight but sometimes found singly; juice white.

Orange-Brown Lactarius

Lactarius volemus

CAP 2 to 4 inches wide; flat to convex when young, later funnel-shaped; golden brown; smooth but sometimes with small pinpoint-sized spots

GILLS decurrent; pale cream or brownish; occasionally forked

STEM 2 to 4 inches long; colored like cap or paler; usually solid and cylindrical.

Scattered throughout Southeast, June through August; juice is white.

Orange-brown lactarius

Cantharellus

Cantharellus species have vase-like, funnel-shaped caps and long decurrent, forked gills that, in most cases, are so thick that they resemble folds rather than gills. The ring and cup are absent and the stem and cap are continuous.

Chanterelle

Cantharellus cibarius

CAP 3 to 8 inches wide; first convex then flat, later shallow and funnel-shaped; margin curved down, wavy; yellowish to buff and orange

GILLS yellow; thick and forking; spores pinkish-yellow or cream

STEM 1 to 3 inches long; thick at top and tapering downward, same color as gills, or lighter

Grows scattered or in groups on the ground, June through August; similar to *Craterellus cantherellus* but has true gills instead of folds.

The chanterelle

Shaggy Chanterelle

Cantharellus floccosus

CAP 2 to 4 inches wide; almost cylindrical with flat top at first, later deeply funnel-shaped; yellow to pale orange and scaly

GILLS ridge-like or folded; forking and pale yellow; spores yellowish-cinnamon

STEM 1 to 2 inches long; not distinct from cap; pale yellow and often covered with white mycelium at base

Fruits from May through September.

Shaggy chanterelle

Hygrophorus

Gills, the principal means of identification, are soft, waxy, and widely spaced; they are not brittle. Gills are sharp at the edges but thicken toward the cap; they are triangular in cross-section. Spores are white. The stem is hollow at maturity and is sometimes twisted and split lengthwise. *Hygrophorus* species are not large mushrooms. The stem and cap are not continuous but do not separate easily from one another.

Scarlet Hygrophorus

Hygrophorus coccineus

CAP 1 to 2 inches wide; conical at first, becoming upturned and wavy; scarlet-red, fading somewhat with age

GILLS orange-red or yellow-orange; alternately long and short; spores white

STEM 1 to 3 inches long; same color as cap but with white base

Grows on the ground in open, grassy woods, July to November.

Scarlet hygrophorus

Russula Hygrophorus

Hygrophorus russula

CAP 2 to 5 inches wide; convex when young, becoming broad and shallow, funnel-shaped; surface pale red to coral pink; sticky when moist, often spotted with very small scales; margin raised and wavy

GILLS white and later spotted with red; attached to stem or short decurrent; spores white

STEM 1 to 3 inches long, tapering downward and covered with downy mycelium

Russula hygrophorus

Grows solitarily on ground, October through December; closely resembles *Russula roseipes*, which has yellow spores.

Tennessee Hygrophorus

Hygrophorus tennesseensis

CAP 2 to 5 inches wide; convex to slightly flat; tawny or clay colored; surface sticky

GILLS white

STEM 2 to 4 inches long; dingy white, tapering downward or occasionally crooked

Found in wet years, September through December.

Tennessee hygrophorus

Clitocybe

Clitocybe have attached or decurrent gills and a tough stem that does not separate readily from the cap. To differentiate between cap and stem flesh it may be necessary to use a hand lens or let the specimen dry. Spores, though generally white, are yellow in some species. The genus is probably best known for the jack-o-lantern mushroom, which glows in the dark. Individuals are not large, but since they occur in groups the total mass is large enough to attract wildlife. They usually occur on decaying wood.

Cartilagenous Clitocybe

Clitocybe cartilaginea

CAP 2 to 4 inches wide; convex; tan to brown in center, becoming pale at edge; surface slick when moist; cap margin on young plants turned in; skin tough, often wrinkled and can be peeled from flesh

GILLS short; decurrent or attached; pale yellow to white

STEM 2 to 8 inches long; rather tough and stringy; slick when moist; several stems often arise from common base

Occurs in mixed hardwoods, October and November; scattered or in dense clumps that resemble fairy rings.

Cartilagenous clitocybe

Cartilagenous clitocybe—sectioned

Jack-O-Lantern Mushroom

Clitocybe illudens

CAP 2 to 8 inches wide; convex at first with margin turned down or inrolled, becoming flat or shallow funnel-shaped at maturity; bright yellow or orange-yellow with dull silky sheen when dry; margin sometimes lobed or wavy

GILLS luminescent; spores pale yellow

STEM 4 to 6 inches long; bases often fused; buff-colored; fibrous and usually curved

Usually grows in dense clumps on and around old stumps, logs, and decaying roots; generally found among mature oaks, May to October; luminescent.

Jack-o-lantern

Parilis

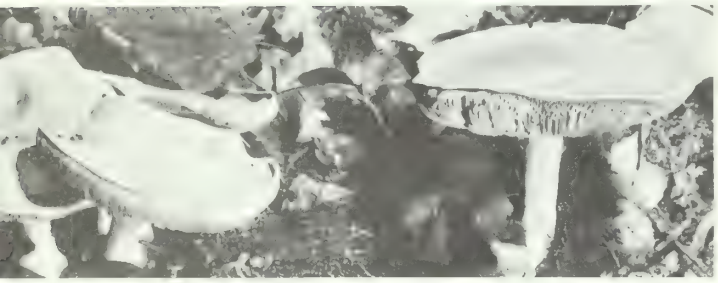
Clitocybe parilis

CAP 2 to 4 inches wide; convex when young, becoming shallow funnel-shaped with maturity; surface grayish tinged with brown, margin curved down or flat; flesh white and thicker near stem

GILLS gray to pale yellow; long decurrent

STEM 1½ to 2 inches long; tapering downward; white or pale gray; base often covered with white mycelium

Grows on the ground near streams and low sites in the mountains, September and October.



Parilis

Mycelium on base of parilis stem

Collybia

Collybias of known value to wildlife grow in groups or clusters on and around hardwood stumps. They are numerous on the Ocala National Forest in Florida and are also found in the upper Coastal Plain and mountains.

Collybia sp.

CAP 1 to 3 inches wide; not continuous with stem and difficult to separate; often enrolled in young plants

GILLS vary from almost free to attached; spores white

STEM tough; thick and fleshy

Collybia

Laccaria

Species of *Laccaria* closely resemble those of both *Hygrophorus* and *Clitocybe*. The waxy gills are well separated and thickened at the base but are pink, which is not a characteristic of *Hygrophorus*. The gills are not attached to the stem, nor decurrent as in *Clitocybe*. In short, *Laccaria* looks like *Hygrophorus* with pink gills. *Laccaria* spores are white.

Waxy Laccaria

Laccaria laccata

CAP ¾ to 2 inches wide; brown to cinnamon, paler when dry or frozen; surface scurfy

GILLS pink; broad; waxy, and free from stem

STEM 1 to 3½ inches long; usually same color as cap; often skin of stem will separate near upper end and resemble a ring, which is fake

Most common of the genus in the Southeast; found mostly in pine types, December and January; withstands freezing well.

Waxy laccaria—note false ring on stem

Waxy laccaria

Purple Laccaria

Laccaria ochropurpurea

CAP 2 to 5 inches wide; grayish when dry, purplish-brown when wet

GILLS bright purple

STEM 1½ to 6 inches long; usually same color as cap, except lighter

Fruits during autumn in mountains.

Tricholoma

Tricholomas have white spores and gills notched at the stem. The stem does not separate readily from the cap. The dividing line between the cap flesh and the stem is often difficult to distinguish. The four species described here are the ones most commonly eaten by wildlife.

Yellow-Brown Tricholoma

Tricholoma flavobrunneum

CAP 2 to 4 inches wide; at first rounded with an umbo, later flat; reddish-tan, sticky when moist; margin incurved for some time, later wavy

GILLS whitish and red-spotted

STEM 2 to 4 inches long; white with red stains

Fruits from August through December.

Yellow-brown tricholoma

Yellowish-Tawny Tricholoma

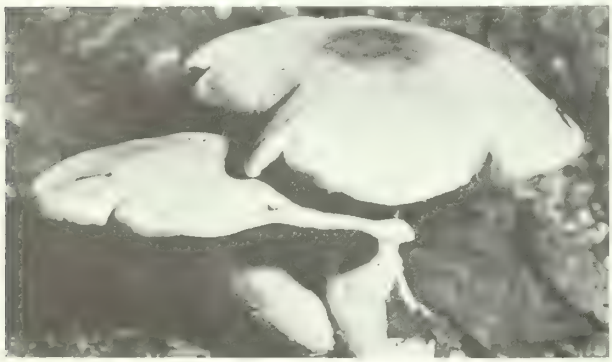
Tricholoma flavovirens

CAP 2 to 5 inches wide; convex at first, later becoming shallow funnel-shaped; wavy margin; tawny color; slightly scaly with a hint of green

GILLS yellow

STEM 1 to 4 inches long; white or tinged with pale yellow

Fruits in October and November.



Yellowish-tawny tricholoma

Lavender Tricholoma

Tricholoma personatum

CAP 2 to 6 inches wide; at first convex, becoming flat; surface at first covered with fuzz; pale watery gray, later turning to pale lavender and becoming naked; flesh pale lavender to gray

Lavender tricholoma

Lavender tricholoma—sectioned

GILLS notched or almost free; same color as cap

STEM 2 to 3 inches long; thick, with enlarged base; color same as cap

Grows in small groups or singly among decaying leaves or brush, September through October.

White-Shining Tricholoma

Tricholoma resplendens

CAP 2 to 4 inches wide; white and sticky

GILLS white with maturity, faintly flesh-tinted

STEM 2 to 6 inches long; white; slightly bulbous at base or with fleshy crook

Occurs in hardwood stands, October and November; usually covered by leaves; squirrels often dig up and eat the enlarged, crooked base, apparently preferring it to the stem or cap.

White-shining tricholoma

Agaricus

The Agaricus species generally have purple-brown spores and a ring. The cap and stem are easily separated. Gills are free. The stalk tapers slightly above the bulbous base. Only three species are common enough to be considered as valuable to wildlife.

Meadow mushroom

Meadow Mushroom

Agaricus campestris

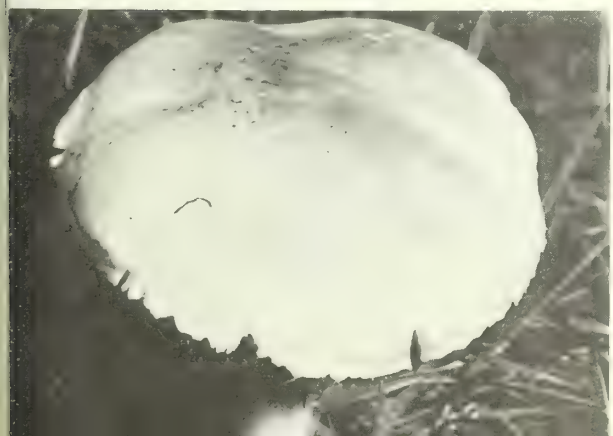
CAP 2 to 4 inches wide; flat with small umbo; surface silky white, tinged with buff or brown, may be delicately scaly

GILLS free; at first bright pink, turning to dark purple-brown with maturity; spores purple-brown

STEM 2 to 4 inches long; white; does not have bulbous base

RING white; thin; fragile with persistent remnants often hanging from edge of cap

Meadow mushroom



Often cultivated; wild species fruits in grassland, meadows, and open hardwood types in May.

Flat-Capped Mushroom

Agaricus placomyces

CAP 2 to 4 inches wide; oval at first, later convex to flat, sometimes with small umbo; white but covered with soft brown scales often concentrically arranged from center of cap; pinkish tint in older caps; flesh white

GILLS at first white, free, later turning pinkish and finally dark brown; spores smoky-brown in mass

STEM 3 to 6 inches long; bulbous base

RING prominent; white and persistent

Fruits in deciduous woods and grassy areas, June through October.

Flat-capped mushroom

Sylvan Mushroom

Agaricus sylvicola

CAP 2 to 4 inches wide; at first long and conical, later convex to flat; silky white with yellow tinge, no scales; turning yellowish with age or injury

GILLS free; crowded; white at first, then dark brown at maturity; spores purple-brown

STEM 3 to 5 inches long; hollow; usually white with bulb at base; flesh turns yellow with injury

RING loosely attached; drooping and may be halfway down stem

Scattered at low elevations in deciduous woods, July and August.

Sylvan mushroom

Cortinarius

Cortinarius has yellow-brown spores; cap and stem are continuous. A distinct cobweb-like inner veil appears on young mushrooms. Remnants of the veil frequently persist on the gills to maturity. Gills may be notched, attached, or short decurrent. *Cortinarius* is most abundant in late summer and fall. Over 100 species of the genus have been described and many are yet to receive attention.

Distant-gilled cortinarius—sectioned

Distant-Gilled Cortinarius

Cortinarius distans

CAP 2 to 4 inches wide; brown and silky when dry, bell-shaped and later convex or flat with an umbo; margin recurved and often split; flesh pale brown to yellow

GILLS may be short notched to short decurrent; often widely spaced

STEM 2 to 4 inches long; brownish with white band of veil often apparent

Fruits from May through December; rodents feed heavily on this species.

Flourishing Cortinarius

Cortinarius evernius

CAP 2 to 5 inches wide; bell-shaped when young, becoming convex to conspicuously elevated on central portion; brown and radially streaked at maturity; radish-like odor

GILLS brown and notched

Flourishing cortinarius

STEM 4 to 6 inches long; gray-wine color
White veil frequently leaves white patches on stem.

Occurs on ground in low, moist woods and along streambanks, August and September.

Scaly Cortinarius

Cortinarius squamulosus

CAP 2 to 5 inches wide; convex; reddish-brown to dark brown; scaly

GILLS notched, dark grayish-purple; veil often persistent to maturity

STEM 2 to 4 inches long, expanded and bulbous at base; ring (remnant of veil) frequently noted on stem

Scaly cortinarius

Pluteus

Pluteus has free gills and pink spores. The stem has neither ring nor volva.

The large fawn-colored pluteus, commonly found in old sawdust piles and decaying wood, fruits in early spring when food is scarce. It grows singly or in clumps of three to eight specimens.

Fawn-Colored Pluteus

Pluteus cervinus

CAP 1½ to 5 inches wide; usually brown to smoky-gray, at times whitish; sticky when wet

GILLS white, then flesh-pink

STEM 3 to 6 inches long; dingy-white; bases often fused

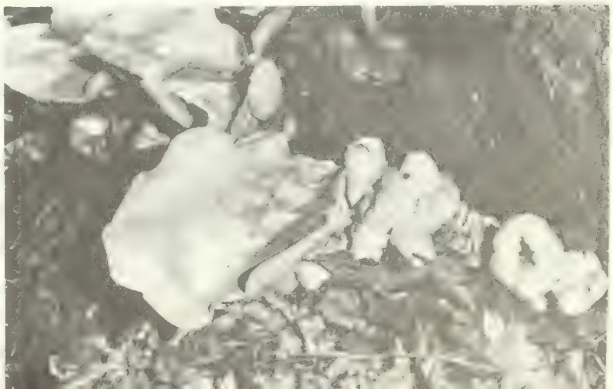
Fawn-colored pluteus

Clitopilus

Spores are pinkish to rosy. The stem is fleshy and at times eccentric. Gills are decurrent. There is no ring or volva.

Plum clitopilus grows near stumps in mountain hardwood types during October and November. It is often associated with an aborted form that appears globular and is intermingled with normal specimens. Both are eaten by animals.

Plum clitopilus (left) with aborted form



Plum Clitopilus

Clitopilus prunulus

CAP 2 to 6 inches wide; at first convex, but later almost flat with wavy decurved margin; surface gray to white, not sticky; flesh white

GILLS long decurrent; white; becoming pink with maturity; pink spore mass often observed on layered caps

STEM 3 to 8 inches long; thick at top, tapering upward; often slightly woolly at base

Evidence that deer are fond of this species

Boletaceae

Members of the Boletaceae are large and common enough to furnish a substantial amount of food to deer as well as to squirrels and other rodents.

Boletes differ from other parasol-shaped mushrooms in that tubes have replaced gills as reproductive surfaces. From the outside the tubes resemble pores; thus the boletes are often referred to as pore mushrooms. Coker and Beers (1943) list 68 species and six varieties in North Carolina; there are probably many more yet to be described. They occur on many sites, but those that grow in the soil appear most attractive to wildlife.

Three important points help to determine genus and species of boletes: ease with which the cap and tubes can be separated, character of the cap and stem surface, and changes in flesh and tube coloring resulting from injury.

Most species of boletes are brilliantly colored. Certain species are noted for their mycorrhizal relationship with several tree species —principally conifers.

Boletes described here are usually found in pine and hardwood forests from the Coastal Plain to the mountains.

Boletellus betula

CAP 2 to 4 inches wide; convex, often pitted and sticky; yellow with red center when young, becoming orange with maturity

TUBES yellow at first, later becoming dark olive-brown

STEM 4 to 8 inches long; slender, often twisted; prominent reticulations yellow; reddish-tinted flesh evident between yellow ridges

(SYN.: *Boletus betula)*

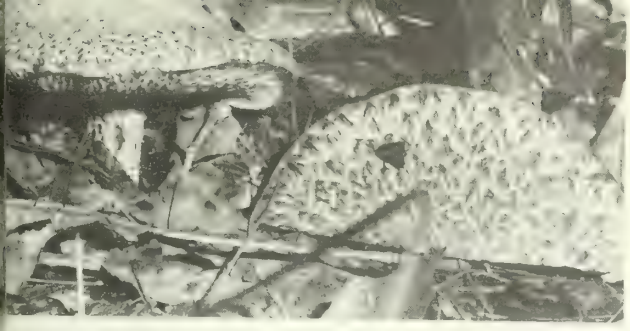
Fruits mainly from July through September.

Typical boletellus betula

Painted Bolete

Boletinus pictus

CAP 2 to 6 inches wide; flat, convex, and slightly sticky; dark red; scaly at first; scales later gently raised at



Painted bolete

edges; yellow upper skin presents mosaic appearance with red scales; flesh creamy yellow, turning reddish when cut

TUBES light brown; cap flesh and tubes do not separate easily

STEM 2 to 3 inches long; same color as cap; may be slightly bulbous at base

Fruits mostly from July through September.

Typical boletus

Two-Colored Bolete

Boletus rubelus

CAP 2 to 6 inches wide; convex; dark rosy red, becoming yellowish and mottled with age; thick flesh whitish at first, later yellow, turning golden with exposure

Two-colored bolete

TUBES depressed around stem; yellow, finally olive or brownish, turning blue very slowly when injured

STEM 3 to 4 inches long; yellow band at top, red below

Fruits in moist sites, August and September.

Gyroporus cyanescens

Gyroporus cyanescens

CAP 3 to 5 inches wide; flat, pitted, and frequently with brownish splotches; flesh pallid but rapidly turning indigo when injured

TUBES brownish-yellow, rapidly turning indigo when injured

STEM 2 to 4 inches long; stout, smooth, and hollow, but loosely filled with fibrous material

(SYN.: *Boletus cyanescens)*

Occurs mainly in young timber stands, July and August.

Pulverboletus retipes

CAP 3 to 7 inches wide; convex; dry; dull yellow to golden; often covered with yellow powder, stains hands if handled; firm flesh light yellow, turning golden when cut

TUBES yellow, turning golden when injured; varying length gives pitted appearance

STEM 3 to 6 inches long; slender and often gently curving; same color as tubes and also powdery; surface strongly reticulated

(SYN.: *Boletus retipes)*

Usually fruits from July through September.

Pulverboletus retipes

Cone-Like Bolete

Strobilomyces floccopus

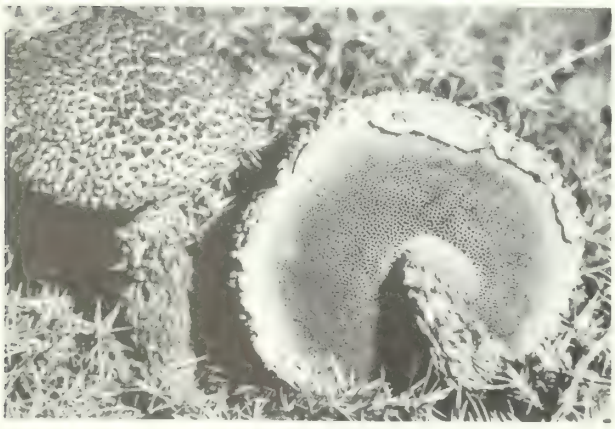
CAP 3 to 7 inches wide; convex, dry and covered with large brownish-black warts and scales; intervening flesh grayish white; remnants of veil frequently found on cap margin; flesh white but rapidly turning nearly black when cut

TUBES grayish white when young, becoming nearly black with age

STEM 4 to 6 inches long; cylindrical; covered with scales same as cap

(SYN.: *Strobilomyces strobilaceus)*

Usually found in pairs, August to October.



Cone-like bolete

Granulated Bolete

Suillus granulatus

CAP 2 to 3 inches wide; flat, convex; slimy and sticky when moist; pinkish-gray to reddish-brown to yellowish or reddish; may have minute scales under slimy surface when wet

TUBES whitish or pale yellow at first, becoming dingy ochre-colored with glandular dots

STEM 1 to 2 inches long; often crooked at lower end; slightly sticky spots darker in color than rest of stalk

(SYN.: *Boletus granulatus)*

Commonly found in pine types, May through November; particularly important to deer on the Ocala National Forest and other sand pine areas in Florida; responsive to fire.

Granulated bolete

Slippery Jack

Suillus luteus

CAP 3 to 5 inches wide; convex; shiny and brownish to reddish-yellow, may be mottled and streaked with darker hues; flesh pale yellow or cream-colored, does not change color when injured

TUBE mouths dotted with sticky particles; spores yellowish-brown or olive-colored

Slippery Jack

STEM 2 to 4 inches long with conspicuous persistent ring; spotted with slimy mucus and droplets of clear liquid

(SYN.: *Boletus luteus)*

Found mainly in pine woods, August through October.

Other Fleshy Fungi

The other fleshy fungi that are commonly aten by wildlife belong mainly to four families: Lycoperdaceae, Clavariaceae, Hymenogastraceae, and Helvellaceae.

Calvatia

This genus belongs to the family Lycoperaceae, a group of fungi known as puffballs, mokeballs, and devil's snuffboxes. These fungi ave spores enclosed until maturity in chamers surrounded by a continuous skin. They pend most of their lifetime underground, geting food from decaying vegetable matter. Vhen about ready to scatter their spores, they merge from the ground.

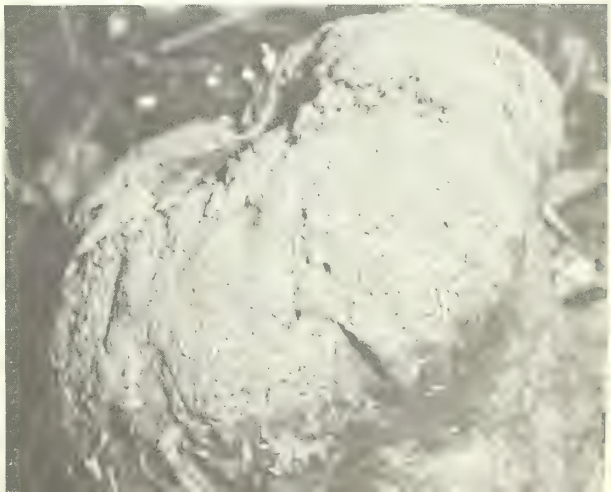
The balls have a fleshy interior; cheesy and hite at first, they turn yellowish or pinkish, radually darkening until part or all of the terior becomes filled with dust-like spores.

In *Calvatia,* the wall of the upper part of he fruit body breaks up and disappears at aturity, thus exposing the spore mass. The alk-like base, with a structure suggesting a oneycomb, may remain in place long after the pores have been blown away.

The giant puffball has a thick tapering base mposed of spongy mycelium, distinct from he spore-bearing part above. It occurs in all rovinces from August to November.

Immature giant puffball

Mature giant puffball



Giant Puffball

Calvatia gigantea

RUITING ODY 6 inches in diameter or larger; smooth exterior; white at first, becoming tan to brown at maturity

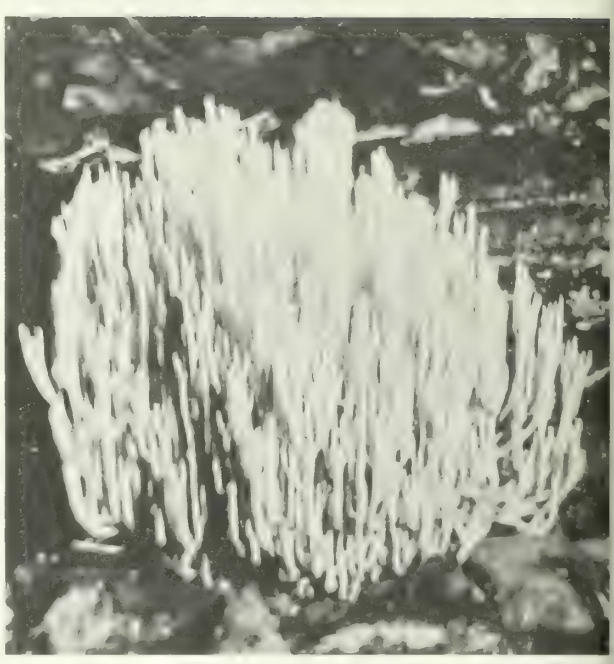
Clavaria

This genus belongs to the family Clavariaceae, the club fungi. It includes a large number of species, many of which are identifiable only by microscopic details. Those eaten by wildlife are fleshy, erect, and repeatedly branched. They are commonly referred to as "coral fungi," because of their resemblance to structures built by this marine animal.

Deer, in particular, graze on the succulent fleshy tops of the coral fungi. Groups of the fungi ranging from 4 to 8 inches in diameter occur in pine and hardwood types. Often these groups number in the hundreds. Clavarias occur from the mountains to the Coastal Plains and fruit during July and August. They do not appear to do well in the fall months.

Clavaria sp.

FRUITING BODY 4 to 8 inches in diameter, usually branched, erect



Typical clavaria

Rhizopogon

Rhizopogon belongs to the family Hymenogastraceae. The fruiting bodies, commonly known as false truffles, form just beneath the surface of the ground. While in the underground stage they are eaten by squirrels and other rodents. They appear to have no attraction once they emerge from the ground.

False truffles generally occur in grassy areas or under pine straw at the edges of pine stands in fall and winter. Careful searching where rodents have been digging may reveal an underground portion that is often from 6 to 12 inches below the surface.

False Truffle

Rhizopogon sp.

FRUITING BODY 1½ to 3 inches in diameter; flat spherical; brownish-black with tough, hard cover over purplish interior

Rhizopogon

Morchella

This genus belongs to the family Helvellaeae, a group that has a fruiting body consisting of a stalk and an enlarged cap that is attached. Some species fruit in recent burns, others in cultivated soil.

In *Morchella,* the morels, the surface of the bell-shaped cap has prominent irregular ridges that resemble the surface of a sponge. The stem is fluted and hollow, often containing holes where insects have emerged; it is lighter in color than the head. The head, or cap, likewise is hollow; darker in color, it is composed of folded, narrow, long, sac-like cells in which the spores are contained. The spores are "squirted" out at maturity.

There are several species of morels in the South. The common morel has the widest distribution and is probably best known. It fruits in March and early April.

Morels grow in deep soils along streams under hardwoods—usually oaks—and in old apple orchards from the Coastal Plain to the mountains. They are readily taken by most mammals.

Common morel

Common Morel

Morchella esculenta

CAP elongated or nearly globose; has deep pits and ridges about 1½ to 3 inches long and about 1 to 2 inches in diameter; gray-brown to yellowish-brown

STALK 1½ to 2 inches long; whitish or yellowish

Common morel sectioned

References

1. Atwood, E. L.
   1941. White-tailed deer foods of the United States. J. Wildlife Manage. 5: 314-332.
2. Charles, V. K.
   1931. Some common mushrooms and how to know them. USDA Circ. 143, 60 pp.
3. Christensen, C. M.
   1965. Common fleshy fungi. 237 pp. Minneapolis, Minn.: Burgess Publishing Co.
4. Coker, W. C., and Beers, A. H.
   1943. The Boletaceae of North Carolina. 96 pp. Chapel Hill, N. C.: Univ. N. C. Press.
5. Dudderar, G. R.
   1967. A survey of the food habits of the gray squirrel *(Sciurus carolinensis)* in Montgomery County, Virginia. M. S. Thesis. Va. Polytech. Inst. Blacksburg, 72 pp.
6. Edminster, F. C.
   1947. The ruffed grouse; its life story, ecology and management. 385 pp. N. Y.: MacMillan Co.
7. Goodrum, P. D.
   1964. The gray squirrel in Texas. Tex. Parks and Wildlife Dep. Bull. 42, 43 pp.
8. Harlow, R. F., and Jones, F. K., Jr.
   1965. The white-tailed deer in Florida. Fla. Game and Freshwater Fish Comm. Tech. Bull. 9, 240 pp.
9. Hessler, L. R.
   1960. Mushrooms of the Great Smokies. 289 pp. Knoxville: Univ. Tenn. Press.
10. Hessler, L. R., and Smith, A. H.
    1963. North American species of Hygrophorus. 416 pp. Knoxville: Univ. Tenn. Press.
11. Hewitt, O. H.
    1967. The wild turkey and its management. 589 pp. Wash., D. C.: Wildlife Soc.
12. Kauffman, C. H.
    1918. The Agaricaceae of Michigan. Reprinted 1965 and 1967 by Johnson Reprint Corp. Vol. 1, 956 pp.; vol. 2, plates.
13. Kavaler, L.
    1965. Mushrooms, molds, and miracles; the strange realm of fungi. 318 pp. N. Y.: John Day Co.
14. Korschgen, L. J.
    1952. A general summary of the foods of Missouri's game and predatory animals. Mo. Conserv. Comm. (P-R 13-R-4), 61 pp.
15. Krieger, L. C. C.
    1967. The mushroom handbook. 560 pp. N. Y.: Dover Publications, Re-publication of the 2nd Ed. 1936 by MacMillan Co.
16. Marshall, N. L.
    1901. The mushroom book. 167 pp. N. Y.: Doubleday, Page and Co.
17. Mendel, L. B.
    1898. The chemical composition and nutritive value of some edible American fungi. Amer. J. Physiol. 1: 225-235.
18. Nixon, C. M., Worley, D. M., and McClain, M. W.
    1968. Food habits of squirrels in southeast Ohio. J. Wildlife Manage. 32: 294-305.
19. Powell, J. A.
    1965. The Florida wild turkey. Fla. Game and Freshwater Fish Comm. Tech. Bull. 8, 28 pp.
20. Smith, A. H.
    1966. The mushroom hunter's field guide. 264 pp. Ann Arbor: Univ. Mich. Press.
21. Strode, D. D.
    1954. The Ocala deer herd. Fla. Game and Freshwater Fish Comm. Game Pub. 1, 42 pp. Fed. Aid Proj. W-32 R.
22. Taylor, W. P.
    1956. The deer of North America. 668 pp. Harrisburg, Penn.: Stackpole Co., Wash., D. C.: Wildlife Manage. Inst.

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ESTABLISHMENT AND EARLY CARE OF SYCAMORE PLANTATIONS

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Southern Forest Experiment Station
Forest Service
U. S. Department of Agriculture

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Figure 1.—*These planted sycamores, just beginning their seventh growing season in the field, average 6.6 inches in diameter and 49 feet in height.*

ESTABLISHMENT AND EARLY CARE OF SYCAMORE PLANTATIONS

C. B. Briscoe[1]

American sycamore (*Platanus occidentalis* L.) has long been planted for soil reclamation and conservation (Clark 1954; DenUyl 1955; Freese 1954), for windbreaks (Read 1958), and for beautification (Li 1957). In 1955, slightly more than 200,000 sycamore seedlings were grown for such purposes (Abbott 1956).

Recently, however, sycamore has been found to provide a high yield of excellent pulp, and the characteristically straight, well-formed logs have come to command a premium wherever a market exists for commercial veneer. Sycamore is a minor component in natural forests, and the only hope of satisfying the burgeoning demand is the establishment of extensive plantations. The wood-using industry is fortunate that, as Michaux wrote in 1857, sycamore is "remarkable for the rapidity of its growth and ease of propagation." A substantial acreage of young plantations now exists, and increasingly large areas are being planted yearly. Nursery production rose 1,500 percent in the past decade (Abbott and Eliason 1968), and demand for seedlings has exceeded supply for 4 consecutive years.

The experience gained by nurserymen, planters, and researchers is summarized in this paper. In order to include the most recent information, visits were made during the winter of 1967-68 to 21 State and industrial nurseries in 16 States; six nurseries in five States were revisited during the 1968 growing season. Plantations were visited at 18 major locations in 13 States.

It would be difficult for anyone to complete the same visits and not finish with an optimistic view of the future for sycamore management. In spite of the great diversity in climate, soils, industrial setting, and personnel, every nursery was producing healthy and vigorous stock, successful plantings were seen at every location, and no major problems had been encountered. Some differences in techniques were found and some minor difficulties had occurred; they are discussed in the appropriate sections of the text.

Production of Planting Stock

Sycamore planting stock is usually grown as 1-0 seedlings. Cuttings from nursery or wild seedlings are usable on moist, well-aerated sites.

SEED

Sycamore seeds are light brown achenes in a round multiple fruit (fig. 2). The descriptive statistics in table 1 are from 17 seed lots gathered in Louisiana and Mississippi in the winter of 1967. The data are not definitive, but they agreed well when compared with information from other areas. Two seed lots from Jesup, Georgia, had only 106,000 and 109,000 seeds per pound,[2] outside the range reported in table 1 but not markedly so. The average yield for the lots represented in the table was almost 58 pounds of clean seed per 100 pounds of fruit—far in excess of a widely quoted figure of 7 pounds per 100 pounds of fruit (Engstrom and Stoeckeler 1941; USDA Forest Service 1948).

Yield.—Sycamores fruit abundantly every year or two (Engstrom and Stoeckeler 1941; McKnight 1969; Merz 1958). Although adverse weather in spring may cause local scarcities (USDA Forest Service

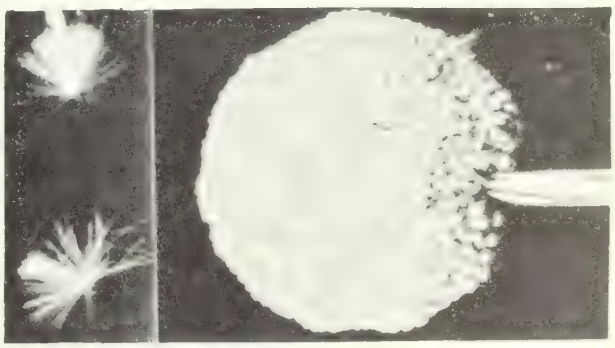

Figure 2.—*Seeds and fruit.*

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[2]Personal correspondence with Frank Vande Linde, Brunswick Pulp and Paper Company, Jan. 31, 1968.

1965), no report has been found of widespread crop failure. Even locally, a few trees seem to have a light to fair crop in the worst of years.

For example, seed was very scarce in the vicinity of Licking, Missouri, in the winter of 1967; of 100 open-grown trees of seedbearing size, 86 had not a single fruit when checked in mid-November. Eight trees had less than 10 fruits each, three had 10 to 100 fruits, two had 100 to 1,000, and one had more than 1,000. Approximately 80 miles to the east, in the vicinity of Fredericktown, most trees had abundant fruits. The following year, the pattern was duplicated almost exactly throughout north-central Mississippi; most trees had no fruit but light to moderate crops occurred on scattered trees. To the north, west, and south of this region the crop was much more abundant.

Production per tree increases with advancing age and size; normal-looking fruits have been seen on trees 3 years after outplanting (4 years from seed), but only in the fifth or sixth year in the field do substantial numbers of trees begin to bear as many as 10 to 20 balls each. Abundance as well as age of fruiting seems to be associated with growing space. Dominant trees yield earlier and produce more fruit than trees of any lesser class, and open-grown trees far exceed forest-grown trees regardless of crown class (fig. 3). The reported minimum seedbearing age of 25 years (USDA Forest Service 1965, p. 491) probably refers to dense natural stands, not to open-grown trees or those in well-spaced plantations.

Site quality presumably influences seed production, with best yields expected on good sites. Information is fragmentary, however, and both precocious and abundant fruiting have been observed on acid spoil banks as well as on rich alluvium.

Estimating seed crop.—At least in the southern part of the range, seed crops can be estimated with fair reliability by counting the number of developing fruits in middle or late April. Few fruits are lost after late spring.

Viability of the seed varies with locality and year. In years when the crop is abundant, each multiple fruit can be expected to yield about 500 viable seeds. In poor years or at poor locations (as where pollen sources are scarce), fruits that appear sound and normal may contain no live seeds (Griggs 1909), or practically none. Lone sycamore trees, in a forest stand or in the open, yield seed of very low germinability because of inadequate cross-pollination combined with poor selfing (Beland and Jones 1967; Webb and Farmer 1968).

Figure 3. *Sycamore with fruit, age 5 years.*

Collection and care of seeds.—Fruits can be collected any time after they turn from green to brown (Bonner 1966a), usually about the end of October near Stoneville, Mississippi (latitude 33°25' N.). There have been reports of deterioration of seeds as the season advances (Bonner 1966a). However, during the 1967-68 season, germination of seed sown immediately after collection improved as the season advanced and was best for collections made in mid-April. Germination of seed sown after 2 to 4 months' cold storage improved similarly, but was at maximum in seed collected during mid-February. Although some seed may persist on the tree through the summer following maturation, none of it is viable. This does not necessarily mean that seed cannot be kept viable at ambient temperatures; quite possibly only sterile seeds persist on the tree.

The most convenient collection is from trees felled after the fruit is ripe but before it shatters. Alternatives include forklift trucks or hydraulic cherry-pickers to raise the worker up in the branches, and a long-handled pruner for clipping the fruit stalk. Small

quantities, especially for research, can be obtained by shooting down branches. Branches to be collected by shooting should be 3 to 5 inches in diameter and positioned within 45° of vertical; they then have enough weight to fall free of other branches, and their angle favors a clean break.

At the end of the season, seed on low branches can sometimes be collected by spreading sheets of material on the ground, then tapping the branches. Near the northern and western limits of sycamore's range intact balls can be collected late in the season from the ground, at least in some years. Great quantities can also be obtained from streets and sidewalks, but the amount of trash collected with such seed makes handling difficult and expensive. Moreover, seeds from known mother trees are to be preferred.

Cleaning seed.—Small quantities of seed are often cleaned by rubbing through hardware cloth (4 to 10 wires per inch) and using a natural or fan-generated breeze to remove the dust and fine hair which cling to the seed. A special apparatus for cleaning small lots is described by Webb and Porterfield (1969). A dust mask must be worn to prevent discomfort, or even pneumonia, from inhaling the hairs. Large quantities are cleaned by passing them through a fertilizer distributor, a hammer mill, or centrifugal disks. The fertilizer distributor is the most widely used, either by pulling it along with the ejection gates closed or attaching a powered belt to a jacked-up wheel (fig. 4). In either case the seeds gravitate to the bottom while the fluff and fruit cores collect at the top or are blown away.

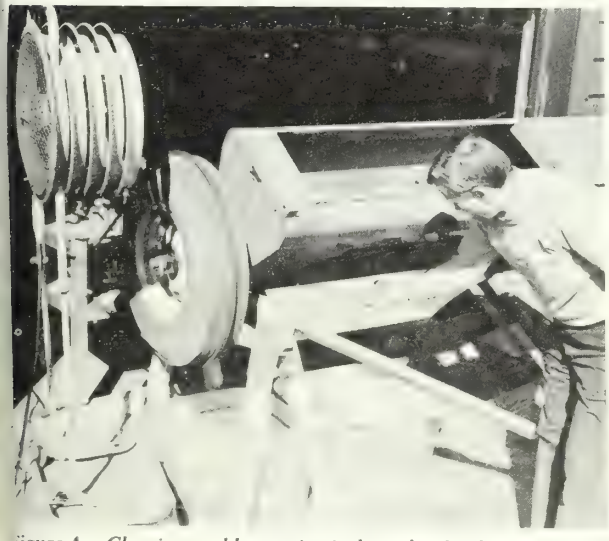


Figure 4.—*Cleaning seed by passing it through a fertilizer spreader.* (Photo by W. A. Chapman, Kimberly-Clark Corporation, Coosa Pines, Alabama.)

Storage.—If the seed is to be sown in the current year, either the fruit or seeds may be stored in a cool, well-ventilated place in an open-mesh bag or spread out on shelves. Seed to be held a year or more should be dried to a moisture content of 10 to 15 percent, placed in airtight containers, and stored at 20 to 38°F. (Belcher 1967).

Pregermination treatment.—Although there are contradictory reports (Bonner 1966a; Engstrom and Stoeckeler 1941; USDA Forest Service 1948), sycamore seed apparently does not have a dormant embryo and does not require stratification (McElwee 1966; Webb and Farmer 1968). If seed is to be stratified, it should be kept moist but well aerated and held between 35 and 38° F. for 20 to 30 days.

Testing.—At the Forest Service's Eastern Tree Seed Laboratory, percentage of sound seed and purity are determined from 1,000-seed samples. Number of seeds per pound is similarly determined, and is expressed on the basis of a 10-percent moisture content.[3] Germination tests are conducted with 100-seed lots, replicated four times. Seeds are placed on moist Kimpack[4] in a closed, transparent container in a room kept dark and at 68°F. for 16 hours of each day and lighted at 86° the other 8 hours. Tests are normally terminated 20 days after sowing.

Germination tests can also be made in water (Briscoe and DuBarry 1959), sand, peat moss, or any of the other media normally used. Some light is necessary for full germination (McDermott 1953).

More than with most species, the results must be interpreted with caution and in the light of local experience. Germination in the nursery may be one-fourth or less of the sound seed (Bonner and Gammage 1967). A rule of thumb at some commercial nurseries is to expect 3,000 seedlings for each pound of seed sown, an average of only 1.5 seedlings per 100 seed. Conversely, yields occasionally are much higher.

Seed purchase.—*Platanus* seed can normally be purchased from the larger seed companies, but unless special arrangements are made there is no guarantee of provenance and in some cases not even of species. In dealing with a genus which occurs completely around the northern hemisphere and a species (*P. occidentalis*) which occurs naturally in at least 34 States and 2 Canadian provinces, a certain amount of variation is to be expected. Seed of known origin should be insisted upon, and a nearby source probably should be chosen if available.

[3] Personal correspondence with Earl W. Belcher, Jr., USDA Forest Service, Eastern Tree Seed Laboratory, Macon, Ga., Oct. 17, 1968

[4] Here and elsewhere in this paper, mention of a product is for information only and does not constitute endorsement by the USDA Forest Service.

Several State nurseries will grow seedlings under contract or from seed provided by the potential planter, and this is a procedure with much to recommend it.

NURSERY SITE AND LAYOUT

Site and layout for a sycamore nursery are similar to those for any tree nursery, but certain requirements are different or more stringent. The small seeds and newly germinated seedlings are easily desiccated and killed. Thus, irrigation facilities are essential. Once wet, seed must be kept wet until germination (Engstrom and Stoeckeler 1941; Lobaev 1950), and the young seedlings require moisture daily until the leaves are about 0.8 inch long (Zmijanac 1956).

Seedlings in the cotyledon stage will not tolerate continuous wind greater than about 10 miles per hour at the soil surface (Lobaev 1950); windbreaks therefore may be necessary in some areas.

Surface drainage must be adequate. Water flowing across the beds will almost invariably remove a substantial portion of the seed.

SEEDLING PRODUCTION

Sowing.—Sycamore seeds are occasionally sown in the fall or late winter, but germination is quicker and more complete if sowing is postponed until middle or late spring. Damping-off is more often a problem in warm soils, however, and drying must be watched carefully where winds tend to be strong and nearly continuous as the season advances.

Seedbed preparation is equivalent to that for any small-seeded species. The beds should be plowed or deep-disked in the fall, and shaped, rototilled, and rolled shortly before they are sown. The surface should be firm and level.

Seeds are commonly broadcast by hand, even in nurseries with annual production in the hundreds of thousands, but they are also broadcast with fertilizer distributors and seed sowers; two nurseries use drills, adding aluminum powder to improve seedflow. Formerly seedlings were often grown in single rows instead of beds (Engstrom and Stoeckeler 1941), but only one nursery is known to be using rows at present. Unless spacing is controlled carefully, seedlings in rows tend to crook severely just above the rootcollar; this may be an important reason why beds have become popular.

Desired density of seedlings varies considerably. Small seedlings are generally preferred for reclamation planting on spoil banks, and nurseries providing such stock may grow 25 to 35 seedlings per square foot of bed space. Larger stock is usually desired for other purposes, however, and recommended bed densities range from 5 to 10 per square foot (Engstrom and Stoeckeler 1941) up to 25 (Vande Linde 1960). Actual densities in State nurseries during the fall of 1967 varied from slightly more than one to as many as 70 per square foot, with eight to 12 the most common.

A final decision on bed density requires balancing nursery costs against anticipated field growth. Large stock costs more to produce, but field survival and growth both increase with increasing diameter at the rootcollar (Engstrom and Stoeckeler 1941; Ike 1962b; Knežević 1956). Among nurserymen providing stock for forest or shade tree plantings—as opposed to spoil bank reclamation—a diameter of 0.25 inch is almost universally agreed upon as the minimum desired. An industrial nursery producing for its own plantings prefers 0.5 inch as minimum. In the 21 nurseries checked, however, not a single bed-width plot was found with more than three 0.25-inch seedlings per square foot (regardless of whether or not smaller seedlings were also present). Existing objectives or practices will have to be changed in order to reconcile desired stocking with desired plant size, but the minimum rootcollar diameter should not be reduced without considerable justification, for large stock is needed in the field.

Sowing rate, in pounds per bed, can be calculated from the widely known formula:

$$\text{Weight} = \frac{(A)(d)}{(n)(g)(s)}$$

where A = area of bed in square feet; d = seedlings desired per square foot of bed; n = seeds per pound converted to the same moisture content at which the seed is to be weighed out for sowing; g = germination percent of the particular seed lot to be sown expressed as a decimal; and s = expected survival expressed as a decimal and referring to the number of plantable seedlings per 100 sound seeds sown.

Another method, much simpler and perhaps as useful, is to determine germination percentage, then sow at the following rates per 100 linear feet of 4-foot bed:

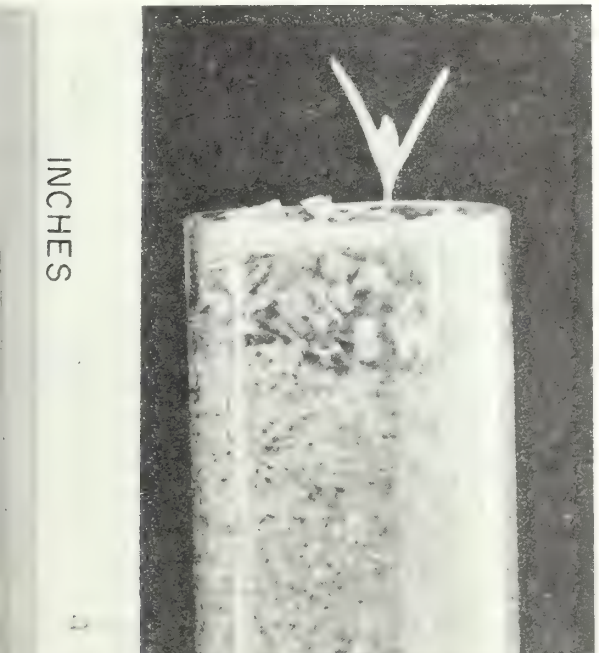
Germination percentage	Sow
	Ounces
10	16
20	8
40	4
80	2

These rates are for air-dry seed and are intended to provide five seedlings per square foot. They should be adjusted as local experience is accumulated. Seedbeds are nearly always mulched to reduce drying and blow-

ng or washing of the light seed and newly germinated eedlings. Sawdust is an excellent mulch; pine needles, at straw, rice straw, and chopped-up pine cones are lso used. The last is unsatisfactory, because seedlings re killed by large fragments of cone.

Because the seedlings have short hypocotyls, hickness of the mulch is critical (fig. 5). Tests at the Forest Service's Southern Hardwoods Laboratory ndicate that 0.25 inch of mulch is preferable to any reater thickness:

Thickness of mulch (inches)	Germination, as a percentage of that with ¼-inch mulch
0.00	30
.25	100
.50	76
.75	75
1.00	48
1.25	30
1.50	3



igure 5.—*Newly emerged seedling. The typically short hypocotyl has barely lifted the cotyledons above the 0.5-inch mulch.*

Care in nursery.—As has been indicated, beds ould be watered often enough to keep the top inch f soil moist until seedlings have several true leaves obaev 1950; Zmijanac 1956). Continued watering is esirable until seedlings are near the size wanted, but mount of water applied can be increased and the pe- od between applications lengthened as the root sys- ms expand.

Shading has been recommended for the first month (Engstrom and Stoeckeler 1941; Zmijanac 1956), but it is rarely done and is apparently unnecessary if seeds and new seedlings are kept adequately watered.

If beds are overdense by the time the seedlings have three to five true leaves, thinning is necessary. Sycamore usually responds to overcrowding by reduction in growth, but mortality has been reported.[5]

Weed competition must be controlled. Presowing fumigation of the beds with methyl bromide, Vapam, Mylone, or Vorlex has controlled weeds, and also limited the development of fungi and nematodes, during the early growing season. Preemergence herbicides are less expensive than fumigants, and Carter and Martin (1967) reported that EPTC, DCPA, chloroxuron, trifluralin, diphenamid, norea, and dichlobenil reduced hand weeding by as much as one-half without damaging the seedlings. Currently, production nurseries depend primarily on hand weeding, but herbicides are likely to be used increasingly.

Cultivation, other than hand weeding, is rare. If seedbed density is held to the recommended level and the seeds sown in narrow rows, mechanical cultivation offers an obvious means of reducing hand weeding.

Fertilization is almost universal. Application is usually with or preceding a cover crop, but a few nurseries add nitrogen directly to the beds of trees. Amount and composition of the fertilizer vary tremendously. There is little information on the nutrient requirements of sycamore seedlings *per se,* other than that the species can be grown on alkaline as well as acid soils (Bonner and Broadfoot 1964).

Pruning.—In order to limit seedling size, tops may be pruned one or more times during the growing season. This type of pruning is normally done with a tractor-mounted rotary mower; height of cut varies from 6 to 10 inches above ground, and the time commonly is from about the first of July to the middle of August—early enough to permit healing of the cuts before the seedlings are lifted and shipped.

Alternatively, the tops may be unpruned during the growing season but trimmed with either a rotary or reciprocating mower prior to lifting; the latter makes a cleaner cut in most cases. Or tops may be trimmed off, usually with a rotary saw, during the packing process.

Seedlings pruned after the growing season are more convenient for packing and planting, particularly the larger seedlings. Early pruning promotes the development of large branches on the lower stem,

[5]Personal correspondence with C. E. Peevy, Louisiana Forestry Commission, Dec. 30, 1968.

whereas dormant-season pruning often removes all branches, leaving a clean, uncluttered stem that takes minimum space in packing and in the planter's box (fig. 6).

Figure 6. -*Top-pruned seedling. The heavily branched stem was pruned in July; the other, after lifting in January.*

Field checks have failed to show that pruning increases the proportion of forked or diseased stems. Height growth of the pruned seedlings is at least as great as for unpruned, but 1 to 3 years may be required for pruned trees to equal the total height of the unpruned.

Nurseries that top-prune during the growing season generally do not root-prune then; and those that root-prune during the growing season usually do not top-prune then.

Root pruning usually has one or more of three objectives: to limit top growth, to modify the pattern of root development, or to restrict size of the root systems. Although the first objective was attained at one nursery by pruning as soon as possible after a heavy irrigation, several nurseries reported no top reduction when root pruning was followed by irrigation; conversely, appreciable mortality occurred when follow-up irrigation was omitted. Thus, reduction of top growth appears to be possible but difficult to obtain.

The second and third objectives are attained without difficulty. Root pruning about mid-July almost invariably promotes development of small laterals and reduces extension of major roots.

Whether or not roots are pruned in mid-season, they are inescapably pruned during lifting. The lifting blade is usually set as shallow as possible, about 6 to 8 inches. Abnormally large lateral roots are sometimes pruned between lifting and packing, and are often pruned by the planting crew. Tests to date indicate no loss in ability to survive and grow even when the taproot is trimmed to less than 4 inches and all laterals are removed. On the other hand, survival and early growth both suffer when seedlings have dried, debarked, or bruised roots.

Thus for sycamore the delivery of seedlings with a large mass of roots is far less important than delivering seedlings on which existing roots have not been allowed to dry. In view of the large investment that goes into production of nursery stock and the greater investments that go into forest plantings, it is important to insure that roots stay moist at every stage of handling.

Inventory.—Because stands of sycamore are generally more variable than those of most other species, more samples or larger plots may be required for a given degree of inventory precision.

Lifting, grading, and shipping.—Sycamore is tardily deciduous, and so is one of the last hardwoods lifted. Northern nurseries usually lift in the fall, heel in, then pack and ship in late winter. Southern nurseries omit heeling in, and commonly lift at any convenient time after December 1. In a Mississippi trial of lifting and planting monthly from August through April, February lifting resulted in slightly the best first-year field growth; survival was very low in August and low in September, but did not vary from October to April.

Culling and grading vary with nursery. A minimum acceptable rootcollar diameter is always established, but it varies from 1/16 to 3/8 inch, with about 1/8 inch the most common. Cull, medium, and large are the only three grades in use, not necessarily by these names. A very few nurseries grade on the basis of height and charge a premium for the largest class. Most grading standards appear to have been arrived at subjectively, rather than by measurement of field performance.

As mentioned earlier, small seedlings have been preferred by many planters for spoil banks. Interest is developing, however, in combining wood production with reclamation. The change is almost sure to bring demand for planting stock capable of fast early growth; this means large-diameter stock with roots

pruned for easy planting and tops pruned to prevent wind whipping on these exposed sites.

Packing material and technique vary considerably, but individual nurserymen universally treat sycamore as they do other hardwoods of similar size. Peat moss is the most widely used material for keeping roots moist. A clay slurry is sometimes applied, wet sawdust is utilized by a few nurserymen, and one nursery ships the seedlings in closed paper bags. An industrial nursery that delivers direct to the planting site omits packaging completely by loading a truck with seedlings and covering the entire mass with moist sawdust; only a few minutes' work at the planting site is necessary to insure that roots are again covered with the sawdust after unloading.

Most bales contain 500 or 1,000 seedlings, depending on size of seedling.

No special measures are required for shipping sycamore, and initial field survival indicates that it stands shipping better than most species.

CUTTING PRODUCTION

Although cuttings generally are less desirable planting stock than seedlings, they can be nursery-grown for annual harvest. The procedure is about the same as for cottonwood cuttings: seedlings or cuttings are planted approximately 1 foot apart in rows 3 to 4 feet apart, to permit mechanical cultivation; they are fertilized as required by the particular soil and irrigated freely until about September 1 or a month before first frost, whichever is earlier. First-year height growth should be 8 to 12 feet in the South, providing four to six cuttings per stem. Cuttings can be harvested from bud-set in the fall until buds begin swelling in the spring.

Unless the planting site is extremely favorable, cuttings should be 16 to 20 inches long and at least 0.3 inch, preferably 0.5 inch, in diameter at the top. There is no known biological limit to the maximum diameter of cutting, but planting techniques usually restrict the usable maximum to about 1.5 inches. Cuttings longer than 20 inches may be required for certain sites.

NURSERY INJURIES

Although not especially prone to damage, American sycamore is attacked by several common nursery pests.

Damping-off may be severe on neutral to slightly alkaline soils. Prevention and control are whatever is standard for the nursery, with Captan 72-S perhaps the most widely used at present for prevention and methylmercury dicyandiamide for control.

The sycamore lace bug (*Corythucha ciliata* (Say)), salt-marsh caterpillar (*Estigmene acrea* (Drury)), tubeworms (*Tetralopha platinella* Clemons, *T. militella* Zell.), and similar herbivores feed on sycamore. Control is by spraying with lindane or malathion either at 10-day intervals or whenever newly hatched larvae appear (Morris 1964).

Sting nematodes (Ruehle 1967) and root rots (Toole 1967) may cause extensive mortality. Proper nursery management, particularly fumigation before sowing, will control them and similar pests.

Young seedlings are resistant to soil flooding (McDermott 1954), and even to submersion (Hosner and Leaf 1962). Neither birds nor rodents prefer the seed or seedling, although there may be sporadic losses to either.

Tender young seedlings are susceptible to freezing (Lobaev 1950); sycamore should not be sown until all danger of hard frosts is past.

Planting

SITE

Selection of site is probably the single most important decision in establishing a sycamore plantation. Although sycamore occurs in nature most often and reaches its maximum size near streams and rivers, it is not confined to such sites and can be seen in coves and on steep slopes (Merz 1958) and even on ridgetops, particularly in the Ozark Mountains. It occurs naturally and grows vigorously on soils that are mildly alkaline (Broadfoot 1964), as well as on acid spoil banks (Einspahr *et al.* 1955; Merz and Plass 1952).

Although trees thrive where ground water is within the root zone, they do not grow well where the soil is flooded or saturated throughout most of the growing season (Bonner 1966b; Hall and Smith 1955).

Sycamore has been successfully planted both to the north (Rosendahl and Butters 1928) and west (Read 1958) of its natural range. It has grown well on sand dunes (Atay 1964), and in the Mississippi Delta has shown excellent initial survival on sandy soils so droughty that planted cottonwood (*Populus deltoides* Bartr.) died out.

For the Midsouth, Broadfoot (1964) recommended sycamore as one of the species to be favored

on the soil series listed below. Not every site on the listed soil series is suitable, of course, and productivity of specific microsites will vary considerably within a single series.

Delta areas

Recent natural-levee soils: Commerce, Crevasse, Mhoon, Robinsonville.

Old natural-levee soils: Beulah, Bosket, Dubbs, Dundee, Forestdale.

Slackwater soils: Alligator, Bowdre, Sharkey, Tunica.

Loess areas

Uplands (moist sites only): Atwood, Brandon, Dulac, Grenada, Lax, Lexington, Memphis-Loring, Natchez, Providence, Tippah.

Terraces: Dexter, Lintonia.

Acid bottoms: Collins, Falaya, Vicksburg, Waverly.

Neutral to alkaline bottoms: Adler, Morganfield.

Coastal Plain bottoms: Bibb, Bruno, Chastain, Iuka, Mantachie, Ochlockonee, Urbo.

Blackland bottoms: Catalpa, Houlka, Kaufman, Leeper, Marietta, Trinity, Tuscumbia, Una, Verona.

Red areas

Terraces: Asa, McKamie, Morse, Muskogee.

Bottoms: Buxin, Gallion, Hebert, Lonoke, Mer Rouge, Miller, Norwood, Perry, Pledger, Portland, Pulaski, Roebuck, Yahola.

Productivity of the silty upland soils of the southern Mississippi Valley has been appraised as follows (Anonymous 1968):

Very high productivity:

Few or no management problems: Adler, Collins, Morganfield, Vicksburg.

Moderate or severe management problems: Arkabutla, Falaya, Routon, flooded Collins.

High productivity: Rosebloom, Waverly.

Moderate productivity: Loring, Memphis.

Broadfoot[6] has devised a subjective method for appraising sycamore site quality by assessing four soil factors: physical condition, nutrient availability, moisture availability during growing season, and soil (table 1). Physical condition seems to be the most important in determining growth and development. On a site with all the "Best" characteristics, as listed in table 1, sycamore would grow about 120 feet in 50 years. Singly, or combined, the characteristics listed in the table under "Poorest" may limit productivity to something less than 90 feet in 50 years.

[6]Personal communication. Walter M. Broadfoot, USDA Forest Service, Southern Hardwoods Laboratory, Stoneville, Miss., June 13, 1969.

Table 1.—*Subjective approach to sycamore site evaluation*

Factor	Determining influence	Characteristics	
		Best site quality	Poorest site quality
Physical condition of soil	Parent material, past use or history, morphology of surface 4 feet of soil	Medium to coarse soil texture Good structure Loose, porous Undisturbed, near-virgin Deep soils (without pans)	Clays Structureless Compacted Cultivated or grazed old fields Soils with pans
Nutrient availability	Past use or history, source of parent material	High in organic matter (>2%) 6 inches or more A horizon Medium to high pH value (5.5 to 8.0) Alluvial soils Young, undeveloped soils	Low in organic matter (<1%) Less than 6 inches A horizon Extremely alkaline (8.5 to 9.0) Extremely acid (<4.5) Upland soils Old, leached soils
Moisture availability	Physiography and position, depth to water table, past use or history	With normal rainfall, soil is moist throughout entire growing season	With normal rainfall, site is dry much of the growing season
Soil aeration	Past use and history, internal drainage	Brightly colored (black, brown, red) soils unmottled to 18 inches	Gray soils Mottled to surface, or with standing water

SITE PREPARATION

Intensive site preparation is important to the best survival and growth of planted seedlings. Sycamore is a species that occurs early in forest successions (USDA Forest Service 1965, p. 490), appearing with other pioneer species that invade abandoned fields, newly formed lands along streams, and similar bared areas (McKnight 1969; Oosting 1942). In plantations, it survives and grows best on sites from which all other living seed plants have been removed. The necessity for such drastic site preparation depends on the productivity of the site. The better the site, the more natural competition there will be, and the more important it is to control such competition. The scattered weeds and occasional vines on a poor site provide little competition to a good seedling, but even unusually sturdy seedlings, as sycamores are, may succumb to the competition of weeds 8 to 12 feet tall or to a solid carpet of vines.

In southern bottom lands outside of the Piedmont, heavy plowing with disks that will cut 4 to 8 inches deep should precede planting of abandoned fields or pastures; the disking should continue until all perennial competition has been thoroughly dried or turned under.

Where rocks or other hazards make such intensive preparation impossible, the site should be planted immediately after clearing in order to give the sycamore seedlings the best possible start on competition that will develop from sprouts and seeds. Only the sturdiest planting stock should be used in such a situation.

Sycamore has been successfully planted under light shade and in small openings, but growth is slow (Biswell 1935). Killing the overstory by girdling or poisoning permits the seedlings to survive, but the higher cost of clearing and burning will almost certainly be repaid by increased yields which will accompany postplanting cultivation. This is particularly true on high-quality sites, where debris must be removed during site preparation to allow for mechanical cultivation.

SEASON AND WEATHER

Like most deciduous trees, sycamore is best planted during the dormant season, with late winter apparently preferable in the Deep South. Preliminary tests have shown some survival from July planting[7] and substantial survival from planting in the period August through April, but only if soil moisture is plentiful at planting and for an extended period afterwards. The qualification cannot be disregarded, since soil moisture is not normally abundant on most sites in August and September. If the tree is in leaf at time of planting, leaves should be removed by stripping or pruning of the stem. Dormant seedlings can be kept in cold storage for at least 4 months, then planted successfully as late as August if ample moisture is provided by rainfall or irrigation.

[7] Personal correspondence with John A. Nugent, International Paper Company, Jan. 24 1969.

PLANTING STOCK

Seedlings.—Planting stock should normally be seedlings. Stem diameter at the groundline should be at least 0.25 inch, and 0.5 inch is better. Little specific information is available on the relation of growth to initial diameter, but Ike (1962b) found that seedlings over 0.5 inch at the rootcollar grew more than twice as much the first year as did those less than 0.3 inch. In a test on two sites in the Mississippi Delta, seedlings with diameters less than 0.2 inch suffered 100 percent mortality while seedlings larger than 0.4 inch showed better than 80 percent survival. Both sites were old fields supporting dense stands of Johnson grass, *Sorghum halepense* (L.) Pers., not a recommended planting condition.

Cuttings.—Sycamore plantations can be established from cuttings (Briscoe 1963; McAlpine 1963; Nelson and Martindale 1957; Toumey 1931). Cuttings have been recommended over seedlings for the closely related oriental plane (Zmijanac 1956) and California sycamore (Mirov and Kraebel 1939), but American sycamore cuttings survive less well than seedlings, grow more slowly initially, are not adapted to as wide a variety of sites, and are generally more expensive to produce and handle. They are currently used much less than are seedlings. Their only apparent advantage, except in tree improvement, is that they can be harvested quickly if natural stands of seedlings or small saplings are available.

Cuttings should be from stems or sprouts less than 4 years old; first-year stems are preferred. Butts have been reported to give better growth than cuttings from the upper portion of the stem (Briscoe 1963; Nelson and Martindale 1957), but the apparent result may have been the effect of cutting size rather than position in the stem. Minimum top diameter should be at least 0.3 inch, with 0.5 inch or larger preferred. Length should be 16 to 20 inches on normal sites, and more on poor sites. In every case the cuttings should be kept moist from collection until planting. Soaking a dried cutting is useless; once dried, a cutting is dead.

PLANTING METHODS

Planting sycamore is essentially like planting any other tree seedling. The objective is to place the existing root system in contact with moist soil, without damage or distortion. It is for this reason that pruning of the seedlings has been mentioned at such length and so often. The more nearly the root system resembles a carrot, the easier it is to care for, handle, and plant. For sycamore, good planting of the carrot is far preferable to poor planting of a larger root system (fig. 7) or careful planting of damaged roots.

Manual planting may be required by the site or the scale of operations. A shovel, mattock, dibble, or planting bar may be used, depending on the stock obtained, the site, and personal preference. The root should be planted at least as deep as it was in the nursery; planting as much as 6 inches deeper has no adverse effects if some of the stem is above the surface soil.

Figure 7.—*Sycamore seedlings, left to right: roots and tops severely pruned, lightly pruned, and unpruned. All three will survive and grow well, but the pruned trees are easier and more economical to handle.*

With cuttings, 2 to 4 inches should normally remain above ground. McAlpine[8] has suggested completely covering long horizontally planted cuttings, presumably for coppicing the resultant dense stands.

Mechanical tree planters usually permit faster, easier, and better planting than hand methods, and the tractor-mounted or tractor-drawn planters developed for pines serve well with sycamore. The utility of a particular model depends primarily on soil type and ground conditions.

Planting large seedlings in deep auger holes, as poplars are sometimes planted (Schreiner 1959; White 1968), has increased survival and height growth the first year (Kaszkurewicz 1967a) and promoted large root systems (Kaszkurewicz 1967b).

SPACING

Optimum spacing varies with management objectives. For example, a stand destined to be thinned for pulpwood should be planted more closely than a stand meant exclusively for saw logs and veneer. Similarly, trees to be cultivated and pruned may be spaced wider than trees not so treated.

On the basis of information now available, the spacings in table 2 are suggested. The number of trees

Table 2.—*Suggested spacings for sycamore plantations*

Desired mean stand d.b.h. at first thinning (inches) (1)	Anticipated stand at time of first cut[1]		Mean stand d.b.h. when natural pruning begins[2] (4)
	Trees per acre (2)	Equivalent square spacing (3)	
	No.	*Feet*	*Inches*
4	538	9	2
6	360	11	3
8	239	13.5	4
10	170	16	5.5
12	134	18	6
14	104	20.5	7.5
16	82	23	9

[1] Surviving trees only. Based on basal area values reported for undisturbed stands by G. H. Lentz, whose 1928 informal reports and charts, entitled "Hardwood Reports, and Addenda," are on file at Southern Hardwoods Laboratory, Stoneville, Miss.

[2] Adapted from information reported by Krajicek (1967).

[8] Personal correspondence with Robert G. McAlpine, USDA Forest Service, Forestry Sciences Laboratory, Athens, Ga., Feb. 6, 1969.

in column 2 and the spacings in column 3 refer to the trees desired at time of first thinning, with no allowance for mortality. If 90 percent survival is expected, the number of trees to plant can be approximated by multiplying 1.1 times the value in column 2. Other assumptions as to mortality will require different adjustment values. The values listed describe the stand characteristics at the time mean annual increment per acre culminates.

Time to reach a given diameter is shortened by adopting spacings wider than those suggested, but yield per acre will drop. Conversely, higher yields per acre can be obtained by closer spacings, but at a given diameter trees will be older and competition will reduce vigor.

Management of sycamore on very short coppice rotations (McAlpine *et al.* 1966) may involve spacings closer than 6 inches by 40 inches; not enough data have accumulated to permit even an informed guess.

REPLANTING AND MIXED PLANTINGS

Sycamore has been used for planting failed spots in plantations of cottonwood and of yellow-poplar, with initial success. It has also been used in mixed plantings, particularly on spoil banks, but it cannot be recommended for this purpose, as it outgrows and dominates most associates (Rodenbach and Olson 1962; Seidel and Brinkman 1962) and dies out or grows slowly if overtopped.

Plantation Care

CULTIVATION AND FERTILIZATION

Many sycamore plantations have been established without postplanting care of any kind. Where large and vigorous stock is used, survival is often excellent. However, consistently best survival and height growth—as much as 12 feet the first year—are obtained with clean cultivation. Observations indicate that cultivation as needed through the first year shortens the rotation by 2 to 3 years or, considered another way, increases the final yield on a good site by 1 to 2,000 board feet per acre.

Cultivation on well-prepared, reasonably level sites should begin as soon as weeds appear above ground. The best care can be obtained by straddle-cultivating until the trees are too large, then cultivating between the rows (fig. 8). Two to five cultivations are required during the first year. On good sites second-year cultivation is unnecessary; its economic effect is not yet known.

Heavy, well-built equipment is essential. Rubber-tired tractors of about 80 hp. are probably best; lighter ones cannot easily pull a heavy disk or a full gang of cultivating plows.

Fertilization may increase growth of sycamore seedlings (Broadfoot and Ike 1967; Funk and Krause 1965; Gilmore and Boggess 1963; Huppuch 1960; Ike 1962a), and small-scale trials are worthwhile. No experimental information is available on the results of fertilizing established stands, nor is growth well correlated with nutrient composition of the leaves (Gilmore 1965).

Phosphorus is most likely to be deficient on coarse, poorly drained soils near the coast and in seedling stands. Addition of nitrogen may increase growth on finer, higher soils and in established stands (Bengtson 1968). Lime, phosphorus, and potassium may be applied up to a year or more before planting and should be incorporated into the soil. Nitrogen in readily available forms leaches rapidly, and hence

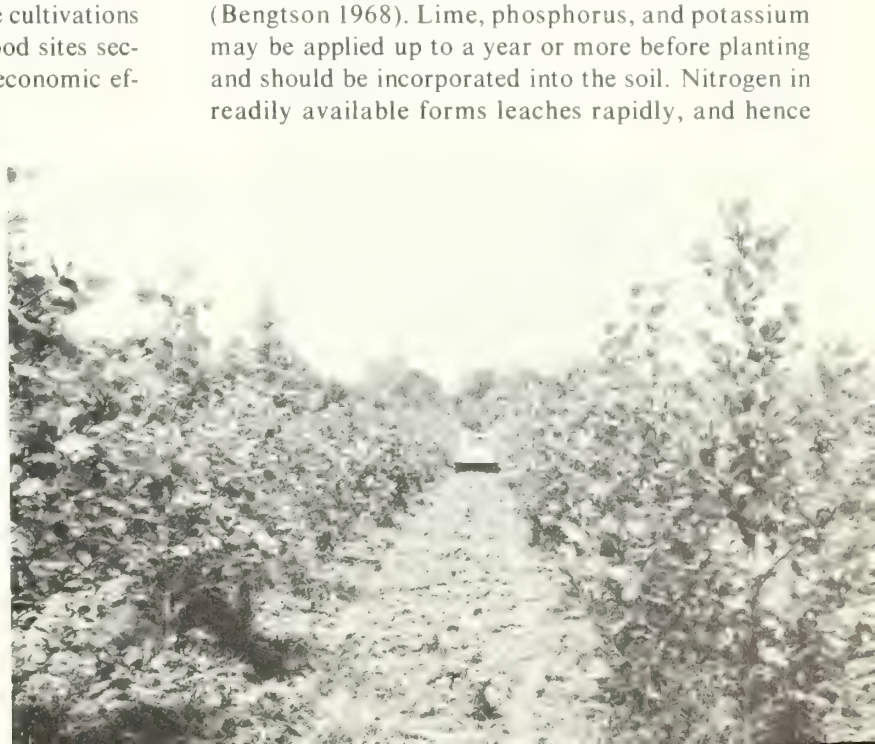


Figure 8.—*A plantation just after a cultivation at the beginning of the second growing season. Such a cultivation is not necessary, but it stimulates growth markedly.*

should be applied just before or sometime after planting, when soil moisture is abundant. If trials are to be carried out, weed competition must be controlled.

Although fertilization will undoubtedly become increasingly important in the future, large-scale application cannot be recommended now.

PROTECTION

Plantations of sycamore are resistant to most agents, but they are not immune. Therefore they must receive the care normally accorded to forest plantings. If fires are not extremely hot, the trees will sprout from the stumps (fig. 9). In plantations that have been heavily invaded by Johnson grass or other weeds, however, a fire during dry weather may destroy the sprouting ability of the rootstocks.

Neither deer nor domestic livestock prefer sycamore seedlings (McKnight 1969), but heavy concentrations of either will strip, trample, and eventually kill young trees. Livestock should be kept out of new plantations. Damage from deer can almost always be held to a tolerable level by planting in blocks of 40 acres or more. Where deer are numerous, small plantings may have to be fenced or established with seedlings more than 4 feet tall.

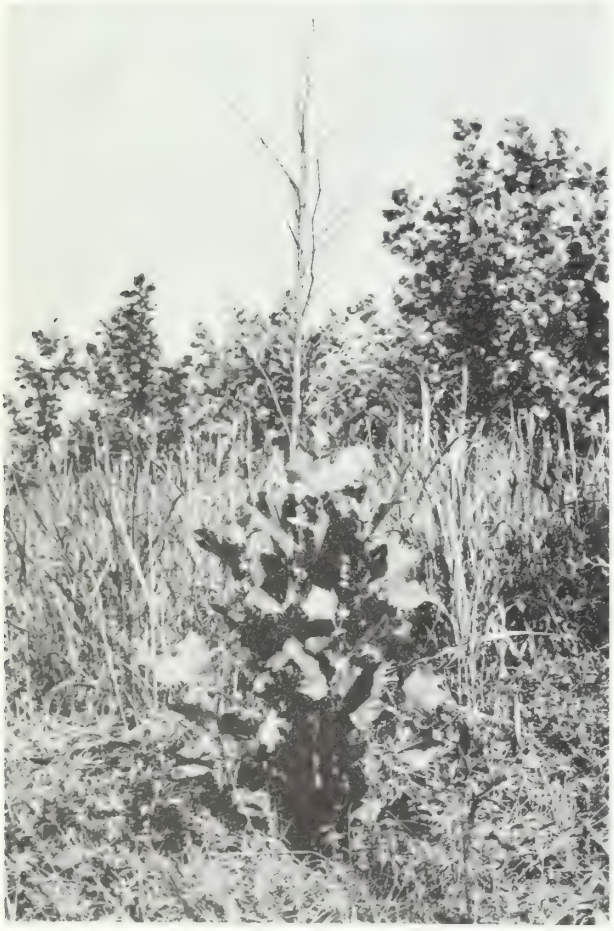


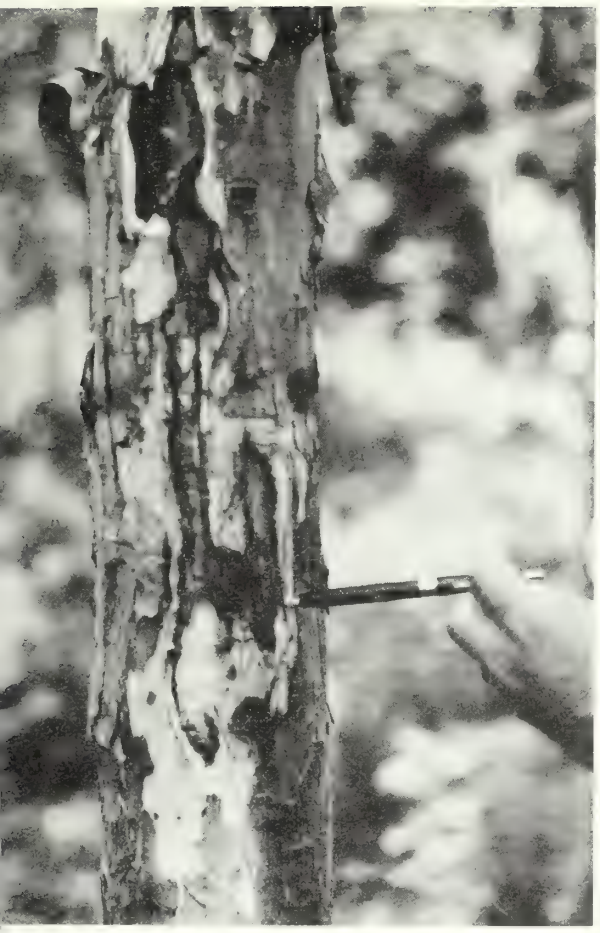
Figure 9.—*Multiple sprouts of a sycamore, 2 years after a hot fire killed the original stem.*

Rodents, presumably rabbits, may clip substantial numbers of seedlings in the spring, but stumps will sprout.

No insects are known to become epidemic on sycamore, although many include it as a host species. Among those causing noticeable damage to foliage of occasional trees are leafhoppers, lacebugs, fall webworm (*Hyphantria cunea* (Drury), aphids, and scale insects. The last are the major pests of the related California sycamore (Smith 1941). The wood is occasionally attacked by the Columbian timber beetle (*Corthylus columbianus* Hopk.), especially on droughty sites, and by the flat-headed sycamore-heartwood borer (*Chalcophora campestris* (Say)), and the hardwood stump borer (*Stenodontes dasystomus* (Say)). While these and other borers may severely damage individual trees, widespread infestations have not been reported (Craighead 1950).

Diseases are of two major types: those that attack leaves and twigs and those that attack the stem. Of the former, anthracnose, caused by *Gnomonia veneta* (Succ. and Speg.) Kleb., is the most common north of the Ohio River (Boewe *et al.* 1954; USDA Forest Service 1967). A light attack partially kills the leaves, so that they look frostbitten; a severe infestation may kill all the leaves and small twigs; growth is then reduced and occasional trees die. The disease is seen less often south of the Ohio River, probably because continuous cool (less than 55° F.), wet weather is requisite for epidemic development of the causal organism (Neely and Himelick 1963). When necessary, control is by application of fungicide (Hoffman 1953; Snyder 1959). American sycamore has been reported both less resistant (Selik 1964) and more resistant (Himelick and Neely 1959; Itô and Hosaka 1950) than related plane trees. Possibly, apparent resistance depends a great deal on the interaction of phenological stage with the weather.

Of stem diseases, the cankers are by far the most important (McAlpine 1961; Thompson 1951). The causal fungi may enter trees of any size through breaks in the bark (Filer 1965), and the cankers spread vertically through the cambium (fig. 10). Heart rot develops beneath the lesions, destroying or degrading the wood and weakening the stem until it is likely to break in a high wind. Fortunately, trees seem to be severely attacked only when drought or other factors have already weakened them, and when the



igure 10.—*Stem canker, caused by* Botryodiplodia theobromae *Pat.*

ause of stress disappears the periods of high inci-ence seem to come to a natural end (Michaux 1857; oole 1961).

Established sycamores are more than ordinarily esistant to drought (Pool 1939) and high winds Alden 1939; Westveld 1939).

THINNING

Thinning of sycamore plantings has received lit-e attention, but there is no reason for expecting re-ults different from those with other species. If the oper original spacing is adopted, no thinning need e made until a merchantable product can be harvest-d. Removing 25 to 40 percent of the stems will then ovide an operable cut and release the remaining ees. Neither epicormic branching (Huppuch 1961) r windfall (Alden 1939; Westveld 1939) has been portant after thinning.

Maximum long-term cellulose yield is obtained thinning from below, although initial financial re-rn from stumpage is minimal. Maximum growth of selected stems only, as for veneer bolts, will be obtained through a crown thinning. Crown thinning will remove larger trees and increase diameter growth of stems released, but total cellulose yield is reduced.

Row thinning offers great advantages, particularly for pulpwood companies, as mechanized harvesters are improved and labor grows scarce.

PRUNING

Natural pruning of sycamore in closed stands is excellent, and dead branches normally fall within 12 to 18 months. In the open, lower branches live almost indefinitely. Thus if stands are kept open to obtain the remarkably rapid diameter growth of which sycamore is capable, artificial pruning will be necessary to hold the knotty core to a minimum.

General guides to pruning are:

1. Prune early. Costs are minimum and returns are maximum if the knotty core is kept small. Approximately 3 inches' diameter outside bark at time of pruning is best.
2. Prune only selected trees. Because complete healing of scars requires nearly an inch of wood outside the cut, 2 inches of growth in diameter outside bark are necessary before any clear wood results. Trees to be removed in early thinning should not be pruned. Pruning a few more than desired for the final crop, to provide for accidents and mortality, is good insurance.
3. Prune only vigorous trees, and prune them moderately. Heavy green pruning reduces growth and may cause epicormic sprouting (Doolittle 1950). But if pruning reduces live crown to not less than 50 percent of total tree height and growing space is adequate, growth is maintained and the epicormic sprouts soon disappear (Doolittle 1956). Stands should not be thinned in the same year they are pruned, as that would accentuate sprouting.
4. Market pruned logs separately under an arrangement that will provide the premium price they deserve.

No meaningful information is available on either the cost or benefit of pruning sycamore. In view of the trees' ability to prune naturally, it appears doubtful that artificial pruning will be justified where markets exist for small products, such as pulpwood. Wide initial spacing accompanied by pruning may well be profitable wherever there is a good market for quality timber but thinnings cannot be sold.

Costs

Although cost of establishing and caring for sycamore plantations will vary with locality, methods, size and type of operation, and weather, some typical costs in the Mississippi Delta are given below.

Operation		Cost per acre
Land clearing: shear, push and burn, rake, and cross-disk		$65.00
Planting:		
Seedlings, at $6 per thousand	$3.00	
Machine planting	5.00	
Total		8.00
Cultivation: 1-way disking, three times		12.00
Total		$85.00

Returns depend on biological and business conditions, and on the assumptions and methods used in accounting. In most areas, mixed products yield much higher returns than pulpwood only (McKnight 1967).

Tree Improvement

Platanus is a promising genus for improvement work, combining a circumglobar range and a wide variety of sites with good interspecific crossability. It is easy to reproduce vegetatively (Kormanik and Brown 1966; Larsen 1946; Nelson 1957) and sexually (Beland and Jones 1967). Current tree improvement research includes wood properties, natural variation, vegetative propagation (Dorman 1966), and plus-tree selection, but no improvements have been reported yet.

Well-spaced sycamore yields abundant crops of fruit at an early age, and trees can be top-pruned for economical harvest of the seed. Thus the species is well adapted for establishing seed orchards of selected or improved trees. The seed orchards should be replicated at widely separated geographical points, to insure a regular supply of seed in spite of vagaries of local weather.

Literature Cited

Anonymous.
1968. Soil survey interpretations for woodlands in the southern Mississippi Valley silty uplands of Arkansas, Kentucky, Mississippi, Missouri, and Tennessee. USDA Soil Conserv. Serv. Progr. Rep. W-4, 18 pp. Fort Worth, Tex.

Abbott, H. G.
1956. Forest tree nursery practices. Amer. Nurseryman 103(6); 17-18, 130-134.

Abbott, H. G., and Eliason, E. J.
1968. Forestry tree nursery practices in the United States. J. Forest. 66: 704, 706, 708-711.

Alden, P. E.
1939. What the summer has taught us about hurricane damage. Natur. Shade Tree Conf. Proc. 15: 100-109.

Atay, I.
1964. [Studies on the stabilization and afforestation of coastal sand dunes in Turkey.] Tar. Bak. Orm. gen. Müd. Yay. 385, 112 pp.

Beland, J. W., and Jones, L.
1967. Self-incompatibility in sycamore. Ninth South. Forest Tree Impr. Conf. Proc. 1967: 56-58.

Belcher, E. W., Jr.
1967. Eastern Tree Seed Laboratory 14th Annual Report. 11 pp. USDA Forest Serv. Southeast. Area, State and Priv. Forest.

Bengtson, G. W.
1968. Fertilizing southern pine forests: does it pay? Proc., Symp. Planted South. Pines, pp. 49-72. USDA Forest Serv., Southeast. Area, State and Priv. Forest.

Biswell, H. H.
1935. Effects of environment upon the root habits of certain deciduous forest trees. Bot. Gaz. 96: 676-708.

Boewe, G. H., Campana, R. J., and Schneider, I. R.
1954. Sycamore anthracnose severe in Illinois. USDA Plant Dis. Reporter 38: 597-598.

Bonner, F. T.
1966a. Handling hardwood seed. Southeast. Area Forest Nurserymen's Conf. Proc. 1966: 163-170. USDA Forest Serv. Southeast. Area, State and Priv. Forest.

Bonner, F. T.
1966b. Survival and first-year growth of hardwoods planted in saturated soils. USDA Forest Serv. Res. Note SO-32, 4 pp. South. Forest Exp. Sta., New Orleans, La.

Bonner, F. T., and Broadfoot, W. M.
1964. Soil nutrients and pH in southern hardwood nurseries. Region 8 Forest Nurserymen's Conf. Proc. 1964: 125-127. USDA Forest Serv. South. Region.

Bonner, F. T., and Gammage, J. L.
1967. Comparison of germination and viability tests for southern hardwood seed. USDA Forest Serv. Tree Planters' Notes 18 (3): 21-23.

Briscoe, C. B.
1963. Rooting cuttings of cottonwood, willow, and sycamore. J. Forest. 61: 51-53.

Briscoe, C. B., and DuBarry, A. P., Jr.
1959. A simplified germination test for American sycamore. USDA Forest Serv. Tree Planters' Notes 35, p. 21.

Broadfoot, W. M.
1964. Soil suitability for hardwoods in the Midsouth. USDA Forest Serv. Res. Note SO-10, 10 pp. South. Forest Exp. Sta., New Orleans, La.

Broadfoot, W. M., and Ike, A. F.
1967. Fertilizing southern hardwoods. Ala. Forest Prod. 10 (7): 41, 43, 45.

Carter, M. C., and Martin, J. W.
1967. Chemical weed control in southern forest nurseries. Auburn Univ. Agr. Exp. Sta. Circ. 156, 12 pp.

Clark, F. B.
1954. Forest planting on strip-mined land in Kansas, Missouri, and Oklahoma. USDA Forest Serv. Cent. States Forest Exp. Sta. Tech. Pap. 141, 33 pp.

Craighead, F. C.
1950. Insect enemies of eastern forests. USDA Misc. Pub. 657, 679 pp.

DenUyl, D.
1955. Hardwood tree planting experiments on strip mine spoil banks of Indiana. Purdue Univ. Agr. Exp. Sta. Bull. 619, 16 pp.

Doolittle, W. T.
1950. Early effects of pruning on the height and diameter growth of sycamore. M. F. Thesis. Duke Univ., Durham, N. C. 56 pp.

Doolittle, W. T.
1956. Pruning sycamore. South. Lumberman 193 (2417): 222-223.

Dorman, K. W.
1966. Forest tree improvement research in the South and Southeast. USDA Forest Serv. Res. Pap. SE-22, 90 pp. Southeast. Forest Exp. Sta., Asheville, N. C.

Einspahr, D. W., McComb, A. L., Riecken, F. F., and Shrader, W. D.
1955. Coal spoil-bank materials as a medium for plant growth. Iowa Acad. Sci. Proc. 62: 329-344.

Engstrom, H. E., and Stoeckeler, J. H.
1941. Nursery practice for trees and shrubs. USDA Misc. Pub. 434, 159 pp.

Filer, T. H., Jr.
1965. Sycamore canker—pesky but not disastrous. South. Lumberman 211 (2632): 169-170.

Freese, F.
1954. Tree species for planting spoil banks in north Alabama. USDA Forest Serv. Tree Planters' Notes 17, pp. 15-18.

Funk, D. T., and Krause, R. R.
1965. Fertilizing strip-mine plantings benefits some hardwoods. USDA Forest Serv. Tree Planters' Notes 71, pp. 21-22.

Gilmore, A. R.
1965. Growth and survival of planted sycamores as related to chemical content of the foliage. Ill. Agr. Exp. Sta. Forest. Note 111, 3 pp.

Gilmore, A. R., and Boggess, W. R.
1963. Effects of past agricultural practices on the survival and growth of planted trees. Soil Sci. Soc. Amer. Proc. 27: 98-102.

Griggs, R. F.
1909. On the characters and relationships of the Platanaceae. Bull. Torrey Bot. Club 36: 389-395.

Hall, T. F., and Smith, G. E.
1955. Effects of flooding on woody plants, West Sandy dewatering project, Kentucky Reservoir. J. Forest. 53: 281-285.

Himelick, E. B., and Neely, D.
1959. Hyperparasitism of a powdery mildew fungus on the London plane tree. Phytopathology 49: 831-832.

Hoffman, P. F.
1953. Results of fungicide tests for control of sycamore anthracnose in 1952. USDA Plant Dis. Reporter 37 (2): 112-113.

Hosner, J. F., and Leaf, A. L.
1962. The effect of soil saturation upon the dry weight, ash content, and nutrient absorption of various bottomland tree seedlings. Soil Sci. Soc. Amer. Proc. 26: 401-404.

Huppuch, C. D.
1960. The effect of site preparation on survival and growth of sycamore cuttings. USDA Forest Serv. Southeast. Forest Exp. Sta. Res. Notes 140, 2 pp.

Huppuch, C. D.
1961. Epicormic branching on sycamore. USDA Forest Serv. Southeast. Forest Exp. Sta. Res. Notes 166, 1 p.

Ike, A. F., Jr.
1962a. Fertilizer nearly doubles Georgia sycamore growth. Crops and Soils 15 (3): 16.

Ike, A. F., Jr.
1962b. Root collar diameter is a good measure of height growth potential of sycamore seedlings. USDA Forest Serv. Tree Planters' Notes 54, pp. 9-11.

Itô, K., and Hosaka, Y.
1950. Notes on some leaf-spot diseases of broad-leaved trees. I. Cercospora leaf spot of plane trees. Meguro Forest Exp. Sta. Bull. 46, pp. 17-36. Tokyo.

Kaszkurewicz, A.
1967a. Planted hardwoods respond to soil-conditioning treatments. La. Agr. 10 (3): 6-7.

Kaszkurewicz, A.
1967b. Research in planting bottomland hardwoods: a progress report. La. State Univ. Forest. Notes 72, 4 pp.

Knežević, I.
1956. Neka zapažanja o uzgoju sadnica platana. [Some remarks on the raising of *Platanus* growing stock.] Šum. List 80 (1/2): 28-30.

Kormanik, P. P., and Brown, C. L.
1967. Epicormic branching and sprouting in hardwoods: a new look at an old problem. Proc., Symp. Hardwoods Piedmont and Coastal Plain, pp. 21-24. Ga. Forest Res. Counc. Macon.

Krajicek, J. E.
1967. Maximum use of minimum acres. Ninth South. Forest Tree Impr. Conf. Proc. 1967: 35-37.

Larsen, C. M.
1946. Experiments with softwood (non-lignified) cuttings of forest trees. Forstl. Forsøgsv. Danm. 17:289-443.

Li, H.-L.
1957. The origin and history of cultivated plane-trees. Trees 17 (5): 7-9, 20, 24-25; (6): 12, 17-18; 18 (1): 12-13.

Lobaev, N. I.
1950. Platan. [Plane.] Lesn. Hoz. 3 (9): 60-61.

McAlpine, R. G.
1961. *Hypoxylon tinctor* associated with a canker on American sycamore trees in Georgia. USDA Plant Dis. Reporter 45: 196-198.

McAlpine, R. G.
1963. A comparison of growth and survival between sycamore seedlings and cuttings. USDA Forest Serv. Res. Note SE-9, 1 p. Southeast. Forest Exp. Sta., Asheville, N.C.

McAlpine, R. G., Brown, C. L., Herrick, A. M., and Ruark, H. E.
1966. "Silage" sycamore. Forest Farmer 26 (1): 6-7, 16.

McDermott, R. E.
1953. Light as a factor in the germination of some bottomland hardwood seeds. J. Forest. 51: 203-204.

McDermott, R. E.
1954. Effects of saturated soil on seedling growth of some bottomland hardwood species. Ecology 35: 36-41.

McElwee, R. L.
1966. Hardwood seedling production—a tree improvement tool. Southeast. Area Forest Nurserymen's Conf. Proc. 1966: 16-22. USDA Forest Serv. Southeast. Area, State and Priv. Forest.

McKnight, J. S.
1967. A new look at hardwood for pulping. Pulp and Pap. 41 (14): 83-84.

McKnight, J. S.
1969. Ecology of four hardwood species. *In* The ecology of southern forests, pp. 99-116. La. State Univ. 17th Annu. Forest. Symp. Proc. 1968. La. State Univ. Press.

Merz, R. W.
1958. Silvical characteristics of American sycamore. USDA Forest Serv. Cent. States Forest Exp. Sta. Misc. Release 26, 20 pp.

Merz, R. W., and Plass, W. T.
1952. Natural forestation on a strip-mined area in Ohio. USDA Forest Serv. Cent. States Forest Exp. Sta., Sta. Notes 68, 2 pp.

Michaux, F. A.
1857. [North American sylva.] Vol. 2. Phila.: D. Rice and A. N. Hart.

Mirov, N. T., and Kraebel, C. J.
1939. Collecting and handling seeds of wild plants. Civilian Conserv. Corps Forest. Pub. 5, 42 pp.

Morris, R. C.
1964. Insects of hardwood nurseries. Region 8 Forest Nurserymen's Conf. Proc. 1964: 142-144. USDA Forest Serv. South. Region.

Neely, D., and Himelick, E. B.
1963. Temperature and sycamore anthracnose severity. USDA Plant Dis. Reporter 47: 171-175.

Nelson, T. C.
1957. Rooting and air-layering some southern hardwoods. Fourth South. Forest Tree Impr. Conf. Proc. 1957: 51-54.

Nelson, T. C., and Martindale, D. L.
1957. Rooting American sycamore cuttings. J. Forest. 55: 532.

Oosting, H. J.
1942. An ecological analysis of the plant communities of Piedmont, North Carolina. Amer. Midland Natur. 28: 1-126.

Pool, R. J.
1939. Some reactions of the vegetation in the towns and cities of Nebraska to the great drought. Bull. Torrey Bot. Club 66: 457-464.

Read, R. A.
1958. The Great Plains shelterbelt in 1954. (Great Plains Agr. Counc. Pub. 16.) Univ. Nebr. Exp. Sta. Bull. 441, 125 pp.

Rodenbach, R. C., and Olson, D. F., Jr.
1962. Five-year survival and height growth of several planted hardwood species in the North Carolina Piedmont. Furniture, Plywood and Veneer Counc. N. C. Forest. Assoc., Inc., Rep. 10, 5 pp.

Rosendahl, C. O., and Butters, F. K.
1928. Trees and shrubs of Minnesota. 385 pp. Minneapolis: Univ. Minn. Press.

Ruehle, J. L.
1967. Sting nematode damage to sycamore seedlings. (Abstr.) Nematologica 13: 151.

Schreiner, E. J.
1959. Production of poplar timber in Europe and its significance and application in the United States. USDA Agr. Handbook 150, 124 pp.

Seidel, K. W., and Brinkman, K. A.
1962. Mixed or pure walnut plantings on strip-mined land in Kansas? USDA Forest Serv. Cent. States Forest Exp. Sta. Tech. Pap. 187, 10 pp.

Selik, M.
1964. [Devastation of plane trees by *Gnomonia veneta* in the neighbourhood of Istanbul.] Istanbul Univ. Orm. Fak. Derg. 14A (2): 124-127.

Smith, R. H.
1941. Sycamore scale in California. Pacific Rural Press 141: 439.

Snyder, H. D.
1959. Control of anthracnose of American sycamore and London plane. Diss. Abstr. 20: 1954.

Thompson, G. E.
1951. Die-back of sycamore. USDA Plant Dis. Reporter 35: 29-30.

Toole, E. R.
1961. New sycamore canker. USDA Plant Dis. Reporter 45: 78.

Toole, E. R.
1967. Root rot of southern hardwood trees caused by *Corticium galactinum*. USDA Plant Dis. Reporter 51: 500-501.

Toumey, J. W.
1931. Seeding and planting in the practice of forestry. Ed. 2, 507 pp. N. Y.: John Wiley and Sons, Inc.

USDA Forest Service.
1948. Woody-plant seed manual. USDA Misc. Pub. 654, 416 pp.

USDA Forest Service.
1965. Silvics of forest trees of the United States. USDA Agr. Handbook 271, 762 pp.

USDA Forest Service.
1967. Sycamore anthracnose. *In* South. Forest Pest Reporter 3, p. 10. Southeast Area, State and Priv. Forest.

Vande Linde, F.
1960. Nursery practice for growing sycamore seedlings. USDA Forest Serv. Tree Planters' Notes 41, pp. 15-16.

Webb, C. D., and Farmer, R. E., Jr.
1968. Sycamore seed germination: the effects of provenance, stratification, temperature, and parent tree. USDA Forest Serv. Res. Note SE-100, 6 pp. Southeast. Forest Exp. Sta., Asheville, N.C.

Webb, C. D., and Porterfield, E. J.
1969. A screen for cleaning small lots of sycamore seed. USDA Forest Serv. Tree Planters' Notes 20(2):26-27.

Westveld, R. H.
1939. Applied silviculture in the United States. 567 pp. N. Y.: John Wiley and Sons, Inc.

White, G.
1968. A technique for deep planting and clean cultivation of cottonwood. J. Forest. 66: 119-122.

Zmijanac, D.
1956. [Rearing plants of *Platanus*.] Šum. List 80 (1/2): 17-23.

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easonal Distribution of Nutrients n Plants of Seven Browse Species in Louisiana

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and
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SOUTHERN FOREST EXPERIMENT STATION
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Seasonal Distribution of Nutrients in Plants of Seven Browse Species in Louisiana

R. M. Blair [1] and E. A. Epps, Jr. [2]

Loblolly-shortleaf pine-hardwood forests provide much of the upland range for white-tailed deer in the South. The understory of this plant community consists primarily of browse growing in association with varying amounts of grasses and forbs. Deer depend upon these ranges for year-round sustenance. To remain healthy and productive, they must obtain an adequate supply of essential nutrients from the native forage or from seasonal supplements provided by man.

Since browse plants are abundant and a significant source of food throughout the year, information on their nutritive content can be very helpful to a deer-management program. This paper reports the results of chemical analyses of two different fractions of current stem tissues and the excised leaves at four seasons for seven common browse species—American beautyberry (*Callicarpa americana* L.), blackgum (*Nyssa sylvatica* Marsh.), sweetgum (*Liquidambar styraciflua* L.), common greenbrier (*Smilax rotundifolia* L.), common sweetleaf (*Symplocos tinctoria* (L.) **L'Hér.**), loblolly pine (*Pinus taeda* L.), and yellow jessamine (*Gelsemium sempervirens* (L.) Ait. f.). The data presented are not intended as a direct determinant of food value but as indicators of the relative forage quality of the species. Firm conclusions about nutritive value must await digestion trials with animals.

Nutrient composition of plants is influenced by many environmental and physiological factors, such as soil, site, climate,

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Sweetgum is a deciduous and shade-tolerant tree of high commercial value. Though seedlings and saplings produce an abundance of browse, they are seldom eaten by deer.

Blackgum, a deciduous and commercially valuable tree, is relatively common in pine-hardwood forests. Leaves and current twigs of seedlings and saplings provide good deer forage.

American beautyberry, a low-growing, deciduous shrub, is abundant in pine-hardwood stands which have a relatively high canopy. It often dominates the low cover in a forest opening. It is thought to be given medium to low preference by deer.

Common greenbrier, a deciduous and shade-tolerant woody vine, abounds in the understory, generally growing into the crowns of low shrubs. The leaves and tender leaders are highly preferred by deer.

Common sweetleaf or horsesugar is an evergreen shrub or small tree common on moist sites with north and east exposures. Leaves and current twigs are highly preferred by deer.

Yellow jessamine, an evergreen woody vine, often blankets the low ground cover, especially in forest openings. Growth occurs even during warm periods in winter. Leaves and current leaders provide highly preferred deer forage year long.

and stage of tissue maturation. Perhaps the most significant variations are associated with tissue maturation and the distribution of nutrients among plant parts. In the present study, such variations were determined during 2 consecutive years, 1960 and 1961. General trends and striking differences between seasons and plant parts are presented in the text. Specific chemical contents of plant fractions, averaged by season for the 2 years, are presented in seven detailed tables at the end of the paper.

Study Area

A 130-acre timbered tract supporting loblolly and shortleaf pines (*P. echinata* Mill.) mixed with hardwoods was selected for study. The area is on an upland site in central Louisiana, 6 miles south of Winnfield on the Kisatchie National Forest.

The terrain is extensively dissected and well drained. It is typical of the Upper Coastal Plain. Elevation ranges from about 140 feet to 225 feet above sea level. Roughly two-thirds of the area consists of gentle undulating terrain; steep slopes and narrow bottoms comprise the remainder.

Soils are heterogeneous.[3] Two closely associated types, Susquehanna and Sawyer very fine sandy loams, are predominant on the ridges and long gentle slopes. Both are acid in reaction and generally low in organic matter and plant nutrients. They are characterized by thinly developed surface soils with slowly permeable subsoils of mottled red, gray, and yellow plastic clay.

Erosion has exposed the heavy clay subsoil on steep slopes. Surface soil from the uplands erodes during periods of heavy rainfall and accumulates in narrow bands along drainage courses.

Prevailing southerly winds during spring and summer provide warm, moist weather, which is interspersed with drier and hotter periods (*10*). Winters are generally mild. The average monthly temperature is 50° F. in January and 83° in July.

The number of days between the last frost in spring and the first in autumn averages 235. The last spring frost was on March 18 in 1960 and on April 16 in 1961.

Growth of most native woody plants is fastest between mid-March and the end of May. Twig growth slows or ceases in early summer, although minor additional growth may occur on some species, especially after summer and early fall rains that break droughts. Long droughts are infrequent. Some broad-leaved evergreens

[3]The soils on the area were surveyed and mapped by Alexander Kerr, Jr., Soil Scientist, USDA Soil Conservation Service, in cooperation with the Dugdemona Soil Conservation District of Louisiana.

grow sporadically during intermittent warm periods throughout the winter.

Forty-seven inches of rain fell in 1960, and 75 inches in 1961; 57 inches is normal. In both years, rainfall was considerably below normal during April and May, the period of maximum growth. A drought extended from early May to late June in 1960. In 1961 heavy rains occurred in February and March and again during the summer.

Timber stands on the study area are uneven-aged. Sawtimber-sized loblolly and shortleaf pines dominate the overstory, and pines and hardwoods make up a multilayered and relatively dense midstory. The common hardwoods are white oak (*Quercus alba* L.), southern red oak (*Q. falcata* Michx.), sweetgum, blackgum, American beech (*Fagus grandifolia* Ehrh.), hickories (*Carya* spp.), red maple (*Acer rubrum* L.), and American holly (*Ilex opaca* Ait.).

Predominant shrubs and woody vines in the understory are American beautyberry, yellow jessamine, common greenbrier, saw greenbrier (*Smilax bona-nox* L.), common sweetleaf, possumhaw (*Ilex decidua* Walt.), common witch-hazel (*Hamamelis virginiana* L.), haws (*Crataegus* spp.), flowering dogwood (*Cornus florida* L.), huckleberries (*Vaccinium* spp.), and arrow-wood viburnum (*Viburnum dentatum* L.).

Fire was excluded from the area for a minimum of 10 years prior to the study. Cattle grazing was negligible and deer browsing was light and sporadic.

PROCEDURE

Collection of Samples

Four deciduous browse species—American beautyberry, blackgum, sweetgum, and common greenbrier and three evergreen species common sweetleaf, loblolly pine, and yellow jessamine were selected for study. Current leaf and twig tissues of American beautyberry, blackgum, common greenbrier, common sweetleaf, and yellow jessamine are considered palatable to deer. Those of sweetgum and loblolly pine are regarded as unpalatable, though they are often ingested on over-used ranges.

The study area was divided into five 26-acre compartments. Samples of current growth were collected from plants selected at random within individual compartments. Only material up to 5 feet above ground (the deer feeding zone) was sampled. It was usually necessary to composite tissue from several proximate plants of an individual species to obtain a sufficiently large sample for chemical analyses.

Material was collected only once from any plant; new plants were selected at each sampling date. Current growth was taken from throughout the crown of each plant. Pine samples were taken only from plants less than 2 feet in height. From January 1960 to October 1961, plant tissues were collected near the middles of January, April, July, and October, the approximate midpoints of the four seasons. The exact sampling time was determined by the stage of plant growth. In spring, parts were taken when new twigs were long enough to yield the desired tissue. Autumn collections were made immediately prior to leaf abscission on deciduous species.

Three portions of the current year's growth twig tips, twig bases, and the leaves from these twig fractions were collected for chemical analyses. On shrubs and trees, twig tips were defined as the terminal 2 inches of stems, and twig bases as the next proximal 4 inches of growth. For vines, the distal 12-inch portion was segmented into 4- and 8-inch fractions.

Only stems ½ inch or more in length were sampled. When current shoots were shorter than 6 inches on shrubs and young trees, or 12 inches on vines, the tip fraction was selected first. The remainder, if any, constituted the basal fraction.

Each sample was placed in an airtight plastic container immediately after collection and weighed at the end of the day to determine fresh or green weight. Containers were then opened and the material dried to a constant weight in a forced-draft oven at 65° F. and reweighed. Dried samples were stored in sealed containers for chemical determinations at the end of each collecting season.

Analyses

Chemical.—All plant fractions were analyzed for percents of crude protein, ether extract, crude fiber, nitrogen-free extract (by difference), ash, phosphorus, and calcium by the Feed and Fertilizer Laboratory, Louisiana Agricultural Experiment Station, Baton Rouge. Chemical contents were determined by standard Association of Official Agricultural Chemists procedures (*1*).

Dry matter is expressed as a percent of green weight, and all other constituents as percentages of ovendry weight. Concentrations of chemical constituents, when expressed on a dry-weight basis, represent relative amounts present in the dry-matter fraction, rather than actual quantities in living tissue. A change in the concentration of a constituent does not necessarily indicate that the living tissue gained or lost a specific amount. Rather, it indicates that the nutrient did not change in proportion to changes in the dry-matter content or to changes in other chemical constituents. Such interactions are

meaningful, as they show that chemical assays, expressed on a dry-weight basis, do not accurately depict physiological activities within live plants (*6*). However, the value of dry-weight analysis as an indicator of forage quality is not lessened.

Statistical.—Analyses of variance were performed for differences in protein, ether extract, calcium, and phosphorus between plant fractions, seasons, and years for individual species. Other chemical constituents were not tested statistically. A factorial design with a mixed model was used to develop expected mean squares for testing the main effects and their interactions. Year and compartment were considered random, while season and plant part were fixed. Precise delineation of interspecific differences was not an objective of the study, and such differences were not tested.

All differences were statistically analyzed at the 5-percent level of probability. The effects of season × plant-part interactions were analyzed by Duncan's Multiple F test (*9*), incorporating Harter's table of critical values (*14*). Only the concentrations of protein and crude fat in sweetgum and calcium in greenbrier differed significantly between years. These differences were attributed primarily to variations in the stage of plant growth at the time of sampling. Hence, the levels of specific nutrients for individual plant fractions and seasons were averaged for the 2 years.

RESULTS AND DISCUSSION

As in previous studies (*3, 13*), notable changes in dry matter, protein, crude fiber, and phosphorus contents were associated with stages of plant growth, as indicated by season. Results of analyses and possible nutritional implications for deer are presented separately for each chemical constituent.

Dry Matter

The dry-matter content of plant tissue is closely associated with palatability and digestibility (*29*). While it may not be possible to say with certainty how digestibility varies seasonally, it is safe to say that older and coarser growth is less readily digested than newer, more succulent and tender spring growth (*2*). Some species, of course, are nonpalatable to deer regardless of their succulence.

In all species, leaves and stems were most succulent in spring, when plant growth was most rapid (fig. 1). Thereafter, the moisture content of all plant parts declined and tissues became more fibrous. Succulence remained low from summer until growth resumed the following spring. The greatest seasonal variation in dry-matter content occurred in the stem fractions.

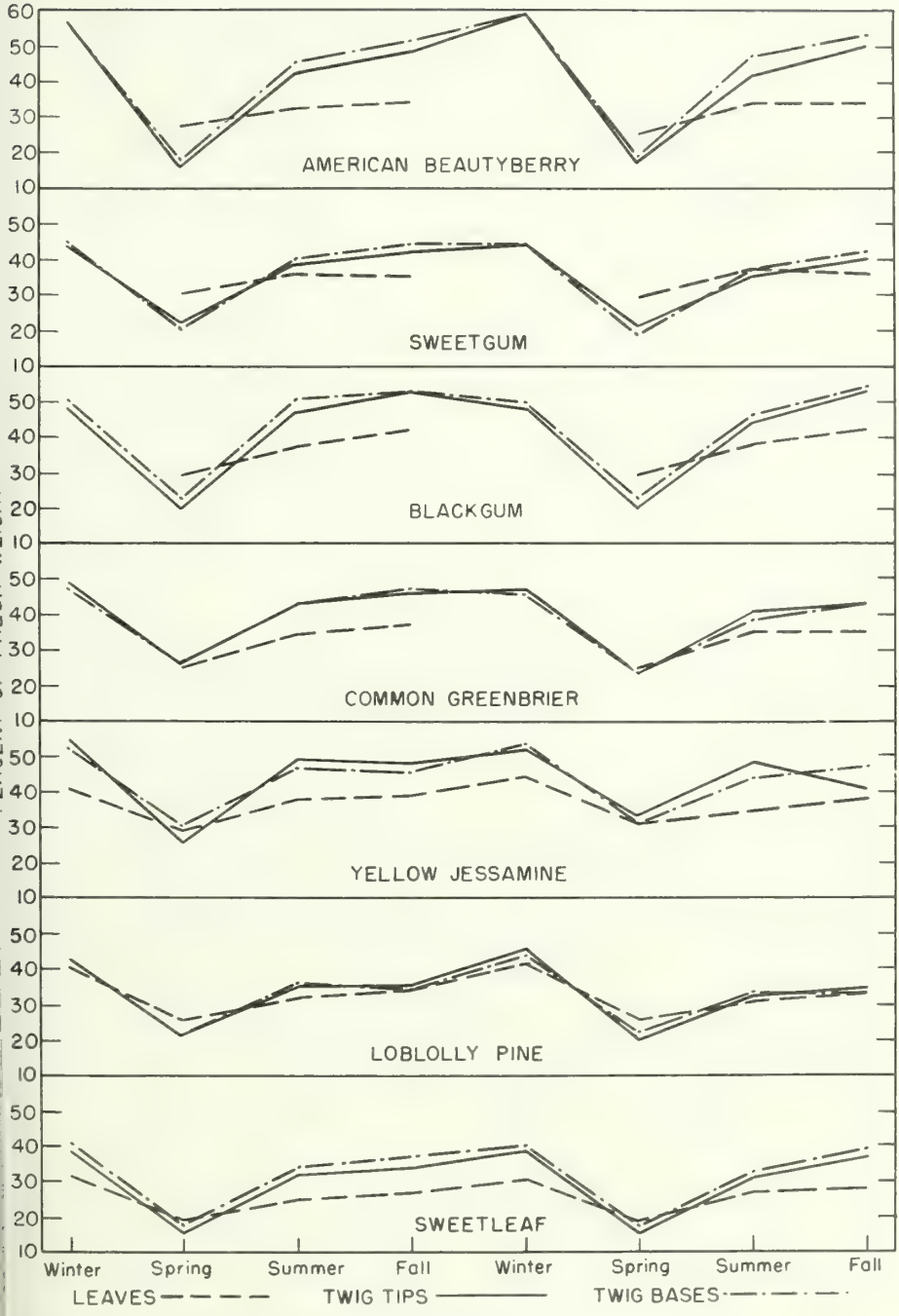

Figure 1.—*Seasonal dry-matter contents of plant parts, 1960-1961.*

Except in spring, leaves were more succulent than twigs; their dry-matter content never exceeded 44 percent. In deciduous species leaves were generally least succulent just prior to abscission in autumn. Moisture content was lowest in evergreen leaves during the winter.

American beautyberry had the greatest seasonal range in dry-matter content of twigs from 18 percent in spring to 58 percent in winter. In other species, dry-matter content of stems did not exceed 55 percent. As expected, twig moisture generally was lowest in winter, and most twig tips were slightly more succulent than basal tissues at all seasons.

Assuming a positive relationship between forage succulence and its palatability and digestibility, leaves and twigs of preferred species were most palatable and digestible in the spring. After tissue maturation, leaves were a better source of succulent forage than twigs. When the dry-matter content of twigs peaked in winter, the leaves of evergreen species were a prime source of relatively succulent tissue.

Protein

The protein content of leaves and twigs of all species, except pine, was highest in spring (fig. 2). At that time, plants were growing most rapidly, and nitrogen was concentrated in the physiologically active cells in leaves and in the meristematic tissues of stems. By midsummer, growth slowed or ceased, and protein content declined appreciably in all plant parts. Levels varied little after the summer, except in leaves of sweetleaf where protein declined to its lowest concentration from autumn to winter.

An abrupt decline in protein concurrent with plant maturation was also described by Taber (*30*) for the chaparral type of California. Others (*6, 7*) report a more gradual seasonal diminution of protein. Since plant phenology influences nutrient trends, differences in the rate of protein decline among species growing in various locales are probably attributable to variations in growth behavior. On southern ranges the growth of many woody species (*3, 13*) slows and ceases during a relatively short period in early summer, and dry-matter and fiber contents increase rapidly. Since protein content is inversely related to fiber content, it declines abruptly as tissues mature.

Seasonal trends in the protein level in young loblolly pine were not the same as those in other species. The protein content of needles was highest in spring, but it was higher in winter than in summer. Twig tips of pine contained the highest percentage of protein in winter, next highest in spring, and lowest in summer and

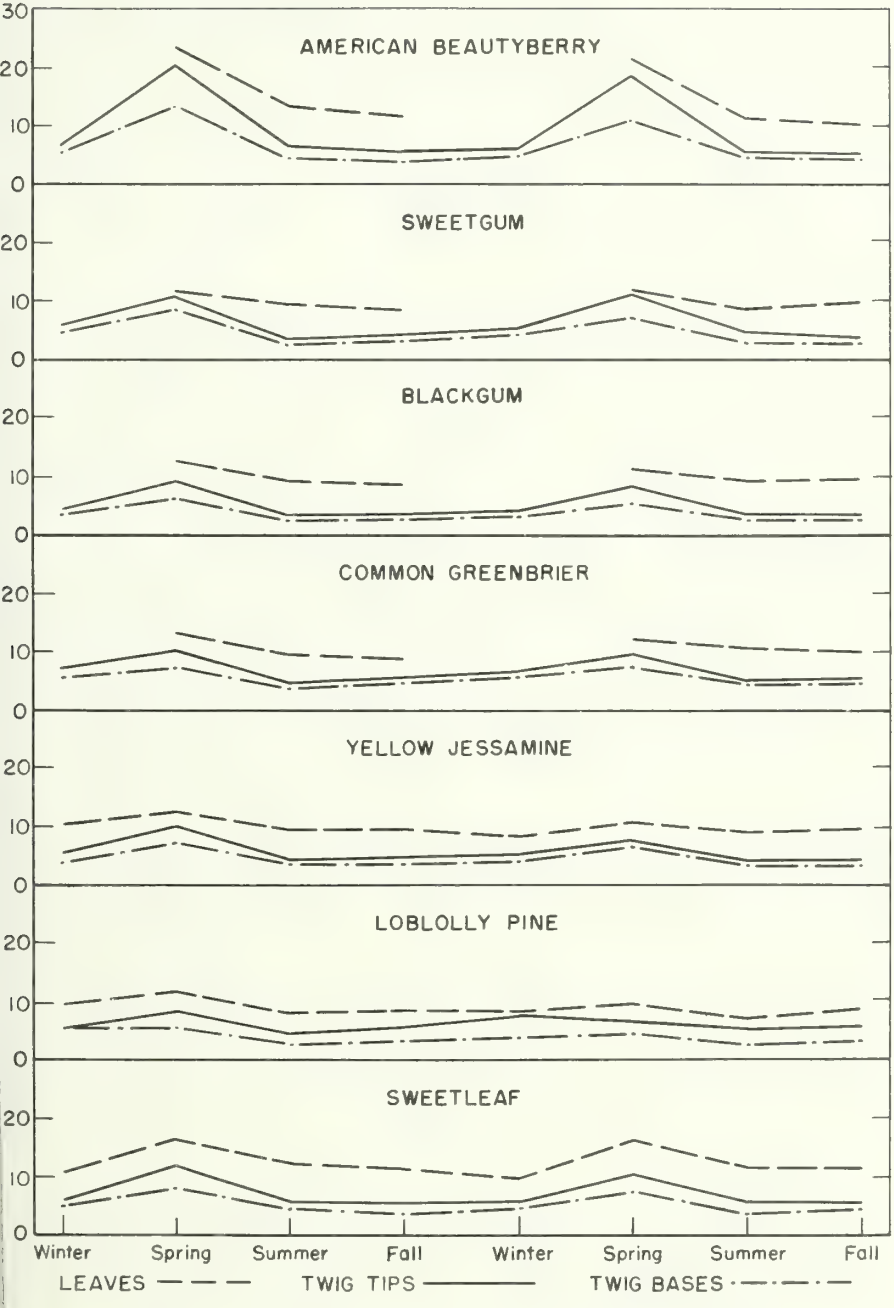

Figure 2.—*Seasonal protein contents of plant parts, 1960-1961.*

fall. There was little seasonal variation in the protein content of twig bases.

Leaves of all species usually contained more protein than twigs at all seasons in which leaves were present. Exceptions were leaves and twig tips of sweetgum, which contained similar protein levels in spring, and needles and twig tips of pine, which contained similar levels in winter. High protein content of leaves has been reported in previous studies (*3, 6, 16, 24*). Kramer and Kozlowski (*16*) attribute it to the high physiological activity of leaves. As leaves develop, nitrogen moves outward from the stems. In deciduous species this transmovement is partially reversed prior to leaf abscission, when a portion of the nitrogen moves back into stem tissues.

Since nitrogen is concentrated in active meristematic tissues, one would expect twig tips to contain more protein than the slightly older basal fractions during periods of rapid growth. Twig tips of all species contained significantly more protein than twig bases in spring. At other seasons there was usually little difference in the content between twig fractions. Exceptions were loblolly pine and sweetleaf, whose twig tips contained more protein than basal fractions at all seasons.

A browsing or grazing animal requires specific quantities of nutrients to maintain body processes and normal muscular activity without weight loss (*11, 28*). The body must be supplied with protein for building and repairing tissue, fats and carbohydrates for producing heat and energy, and minerals, especially calcium and phosphorus, for building bone and carrying on numerous body functions. Only after this maintenance requirement is met can growth and fattening take place. Since the nutrient requirements of deer on southern ranges have not been determined, they must be extrapolated from research findings elsewhere. Nutrient needs obviously vary according to the physiological demands of individual animals and their digestive efficiency at different seasons.

The protein requirement for optimal growth of young deer appears to be about 13 to 16 percent of the daily dry-matter intake (*11, 20*). About 7 percent is needed for maintenance. Feeding trials (*19*) have indicated that mature bucks require less protein, calcium, and phosphorus for body growth and antler development than young, vigorously growing deer.

Among the three plant parts and seven species studied, only leaves and twig tips of American beautyberry and leaves of greenbrier and sweetleaf contained the 13 percent protein required for growth, and then only in spring. Leaf tissue contained maintenance levels of protein in all seasons in which leaves were present. Twig tips of most

species contained sufficient protein for maintenance only in spring.

Twig bases were a poor source of protein. Those of American beautyberry, sweetgum, greenbrier, sweetleaf, and yellow jessamine exceeded the maintenance level in spring; those of blackgum and pine were always below it.

Low protein contents of twigs, even during spring, have previously been reported both in the South (*3, 5, 17, 18*) and elsewhere (*6, 7, 15, 26, 27*). Since leaves are the best source of protein, the broad-leaved evergreens are particularly important during winter, when quality of other forage is low. Deer undoubtedly feed on other plants higher in protein than the ones studied, such as herbaceous legumes, and thereby compensate for the low levels in many browse species.

Ether Extract

Seasonal trends in ether extract or crude fat were erratic (fig. 3). Except in pine, plant tissues, especially twigs, were relatively low in fat content. A sizable proportion of the ether extractable material in pine tissues undoubtedly consisted of resins and oils.

Ether extract in leaf tissues of most species tended to increase slowly with seasonal progression. Consequently, leaves of deciduous species, except sweetgum, contained significantly more fat in autumn, and leaves of evergreen species contained more in autumn and winter, than in the spring. The percentage of fat in sweetgum leaves varied little over the year.

Seasonal changes in crude-fat contents of twigs of deciduous species were small. Twig tips of the evergreen yellow jessamine had the highest fat levels in spring, while twigs of young pine contained the most fat in winter. Other seasonal variations in evergreens were minor.

Leaves of all species except sweetgum, blackgum, and loblolly pine usually contained considerably more crude fat than did twigs. Twigs and leaves of sweetgum had similar fat contents in all seasons, and blackgum leaves contained more than twigs only in the fall. Twig tips of pine frequently contained as much or more ether extract than needles or twig bases.

The terminal and basal segments of twigs from other species generally contained similar percentages of crude fat throughout the year.

Crude fat is an important energy source for deer. While a precise dietary requirement has not been determined, the animals seldom appear to lack this constituent in their diet. Leaves tended to be a

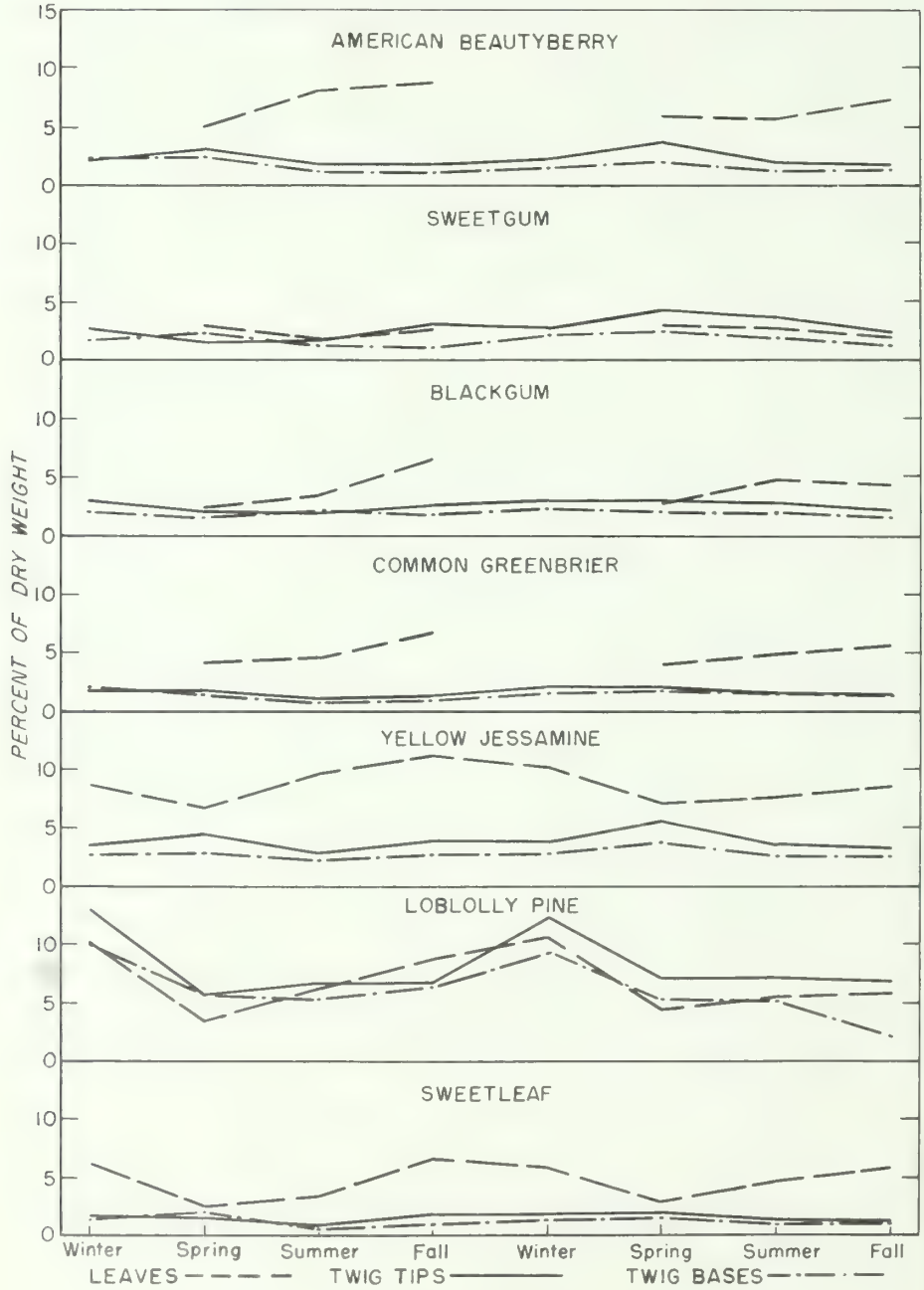

Figure 3.–*Seasonal ether-extract contents of plant parts, 1960-1961.*

etter source of crude fat than twigs, especially in summer and utumn, when deer are storing body fat. Similar findings were eported by Cook and Harris (*6*) for browse species in Utah.

rude Fiber

Crude fiber was lowest in twigs during spring, when plants were ıcculent and growing vigorously (fig. 4). It increased substantially by idsummer after growth had virtually ceased and remained high the st of the year.

Moderate declines in the percentage of crude fiber in twigs, after summer or fall peak, can be attributed to variations in other iemical constituents of dry matter. In living twig tissues, crude fiber ctually increased gradually from summer to winter. With crude fiber xpressed as a percent of the dry matter, however, seasonal declines mature tissues are common (*8, 15, 17, 27*).

The crude-fiber content of leaves changed little during the year.

Except in pine in the spring, leaves of all species were less brous than twigs. Twig tips were less fibrous than twig bases.

Since forages high in fiber are less digestible and, therefore, less utritious than those lower in fiber (*23, 25, 32*), leaves were more utritious than twigs, and twig tips were superior to twig bases. On outhern ranges, the leaves of many broad-leaved evergreens are robably particularly valuable deer food in late fall and winter, since iey appear to be relatively low in fiber and to provide a fair source f protein in comparison with twigs of either deciduous or evergreen pecies.

itrogen-Free Extract

Nitrogen-free extract (NFE) includes the readily digestible arbohydrates in plant tissue, as well as some indigestible lignin (*31*). oluble carbohydrates are a readily available source of energy.

Seasonal trends in the NFE content of plant tissues were mewhat erratic (fig. 5). As growth matured, the percentage of NFE creased appreciably in leaves of American beautyberry and veetleaf but only slightly, or not at all, in other species.

The NFE content of both twig fractions of sweetgum, blackgum, eenbrier, and pine was slightly higher in spring than at other asons. In contrast, mature twigs of American beautyberry, yellow ssamine, and sweetleaf generally contained considerably more NFE an spring tissues.

Except for pine needles in spring, leaves usually contained a gher percentage of NFE than twigs. Twig tips generally had higher vels than twig bases.

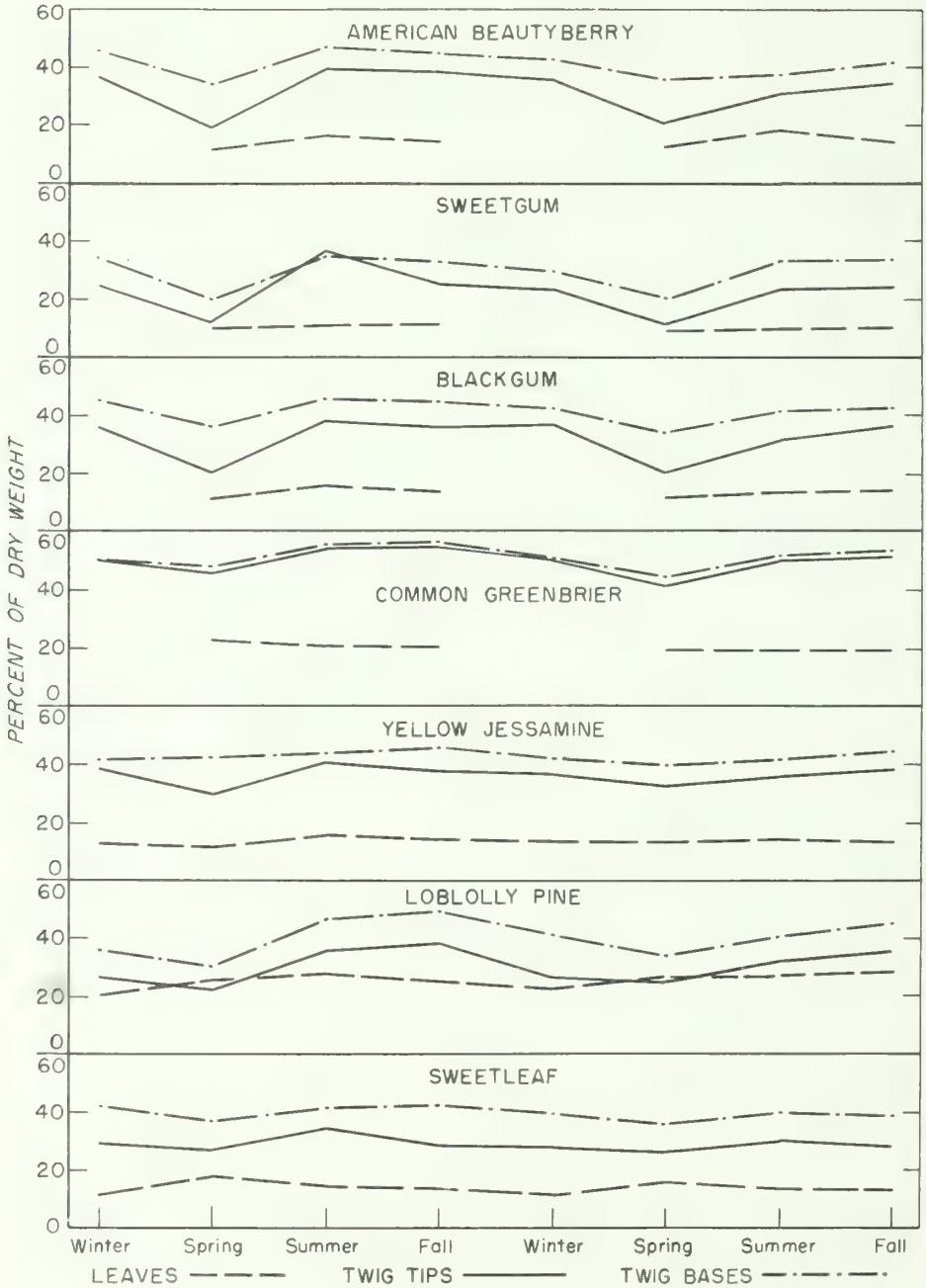

Figure 4.—*Seasonal crude-fiber contents of plant parts, 1960-1961.*

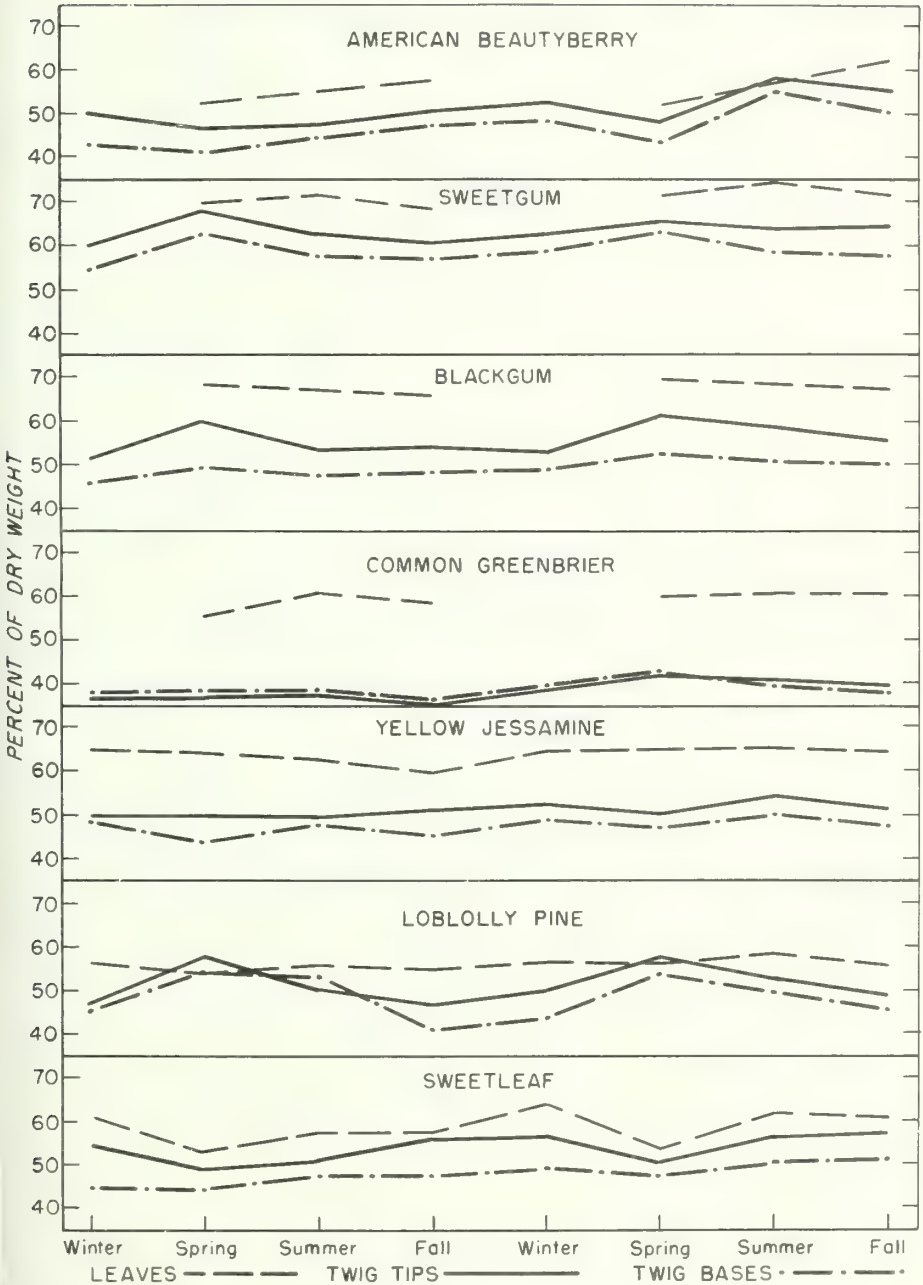

Figure 5.—*Seasonal nitrogen-free-extract contents of plant parts, 1960-1961.*

Twigs of deciduous and evergreen species provided comparable amounts of NFE during autumn and winter. Because of the presence of leaves, however, the broad-leaved evergreens were a better source of soluble carbohydrates in late fall and winter.

Ash

In leaves, mineral content varied erratically by species, season, and year (fig. 6). For example, in 1960 the ash content of American beautyberry leaves was lowest in the spring and highest in the fall, while in 1961 the opposite was true.

Trends in twig tissues were considerably more orderly. The percentage of ash in twigs of all species was highest in spring, and declined sharply as stems matured. Ash levels fluctuated little from summer to winter, except in sweetgum twigs, which contained the least in summer.

Leaves of American beautyberry, sweetgum, and blackgum contained less ash than twigs in the spring, but leaves contained more at other seasons. In the remaining species, leaves generally had as much, and usually more, mineral than twigs in all seasons. Twig tips seasonally contained more ash than twig bases.

High ash content of forages is very important to deer, especially in skeletal formation and for well-developed and hardened antlers on bucks (*8*). As tissues matured, leaves of all species but pine were generally a better source of minerals than twigs.

Calcium

The percentage of calcium in leaves of all species, except pine, increased significantly from spring to summer (fig. 7). In American beautyberry and yellow jessamine, this increase continued as the year progressed; in other species the content varied little following growth maturation. With growth extending well into summer for young loblolly pine, calcium in needles varied little from spring to autumn; the level did increase in late autumn or winter.

Calcium trends in twig tips were generally similar to those in leaves. In sweetgum, blackgum, yellow jessamine, and sweetleaf, the percentage of calcium increased as twigs matured, and levels tended to be highest in autumn and winter. Variations between seasons were small for American beautyberry, greenbrier, and pine. The only significant seasonal differences in percentage of calcium in twig bases were in the evergreen species, where fall and winter levels were generally higher than those of spring.

Differences in seasonal distribution of calcium among plant fractions varied considerably. Leaves of American beautyberry,

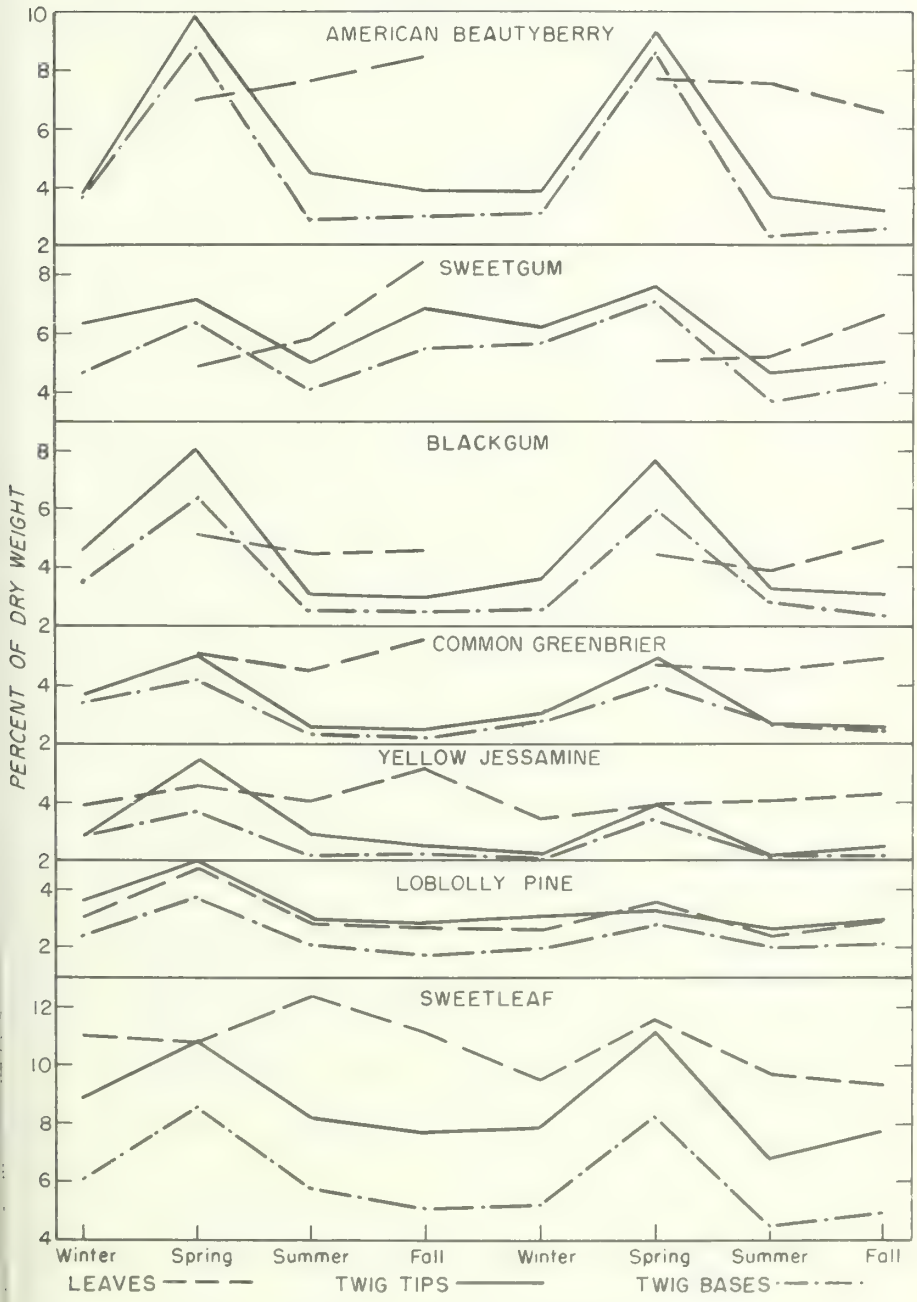

Figure 6.—*Seasonal ash contents of plant parts, 1960-1961.*

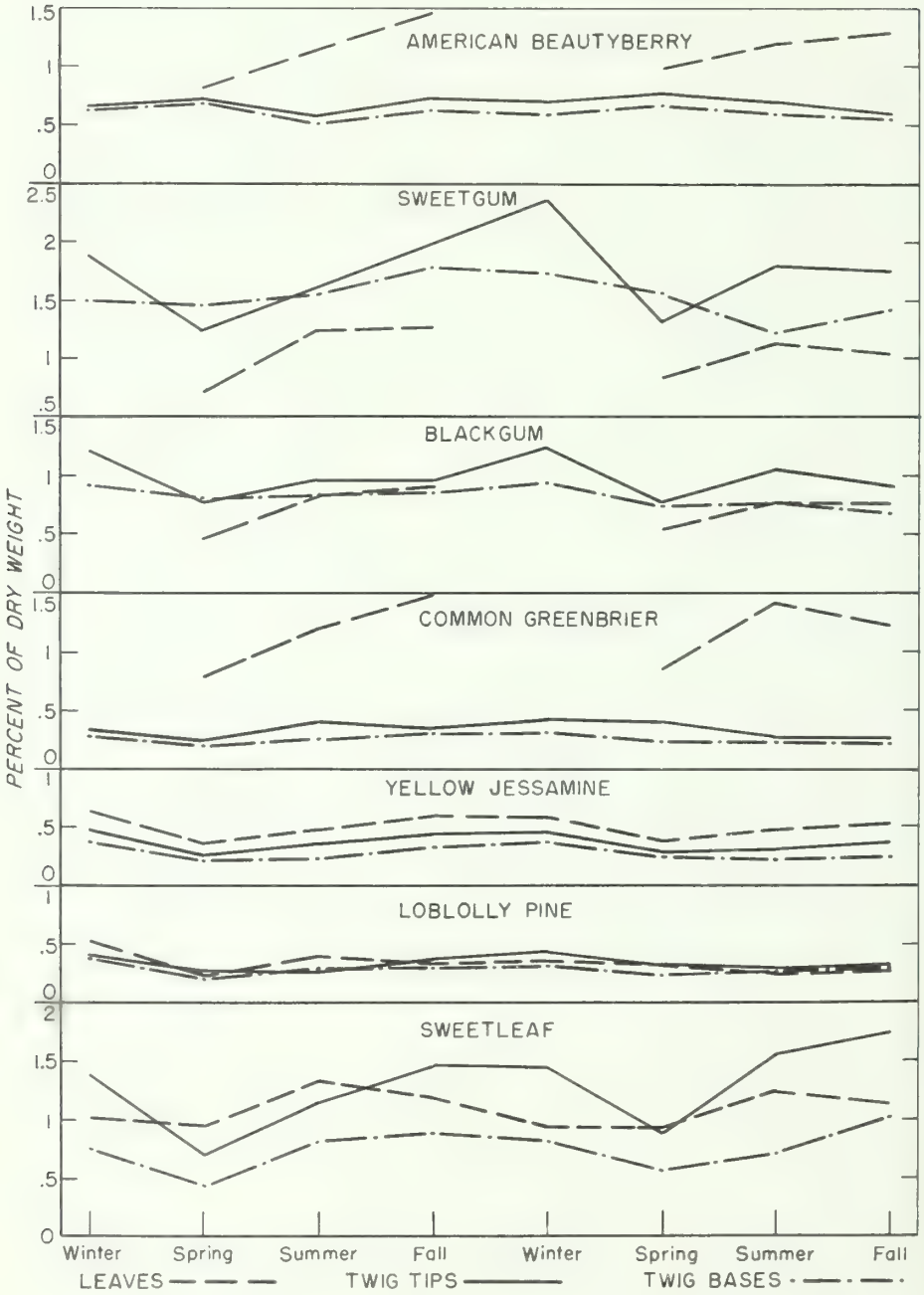

Figure 7.–*Seasonal calcium contents of plant parts, 1960-1961.*

greenbrier, and yellow jessamine contained more than twigs at all seasons in which leaves were present. Those of sweetgum, blackgum, and sweetleaf tended to contain less calcium than twigs, and especially twig tips. Seasonal levels differed little among the plant fractions of pine.

Twig tips of sweetgum, blackgum, yellow jessamine, and sweetleaf generally contained more calcium at all seasons than the slightly older and more fibrous twig bases. Levels did not vary by season between stem fractions of American beautyberry, greenbrier, or loblolly pine.

Calcium is required by deer for skeletal and antler development. Dietary requirements are not well known, but feeding trials (*20*) have indicated that the daily calcium requirement for optimum deer growth is about 0.64 percent of the ingested dry matter. About 0.25 to 0.30 percent appears to be the minimum for animal maintenance.

Southern range plants apparently are seldom deficient in calcium. Leaves and twigs, and especially twig tips, of American beautyberry, sweetgum, blackgum, and sweetleaf, as well as the leaves of greenbrier, generally provided sufficient calcium at all seasons for deer growth. Maintenance requirements were met in all seasons by yellow jessamine leaves. The twig tips of this species and those of greenbrier contained maintenance levels from summer to winter. All pine tissues and the twig bases of greenbrier and yellow jessamine were the poorest sources of dietary calcium; they generally provided maintenance levels only in autumn and winter.

Phosphorus

Seasonal trends in the phosphorus content of all species were similar and appeared to be closely associated with plant growth (*13*). High levels in spring dropped appreciably with the cessation of growth. Similar findings have previously been reported (*3*). Like protein, phosphorus tends to accumulate in actively growing tissues, with considerable transmovement from twigs into newly developing leaves. A portion of the phosphorus moves back into the twigs as leaf tissues become senescent (*16*).

The percentage of phosphorus was highest in the spring in all tissues of all species except pine, whose twig tips contained the most in the winter (fig. 8). With growth maturation, levels declined sharply, and the content generally varied little thereafter in leaves and stems of American beautyberry, sweetgum, and greenbrier, and in twigs of blackgum and yellow jessamine. In leaves of blackgum and yellow jessamine and in leaves and twigs of pine and sweetleaf, phosphorus content usually reached a low in midsummer, after which it increased significantly.

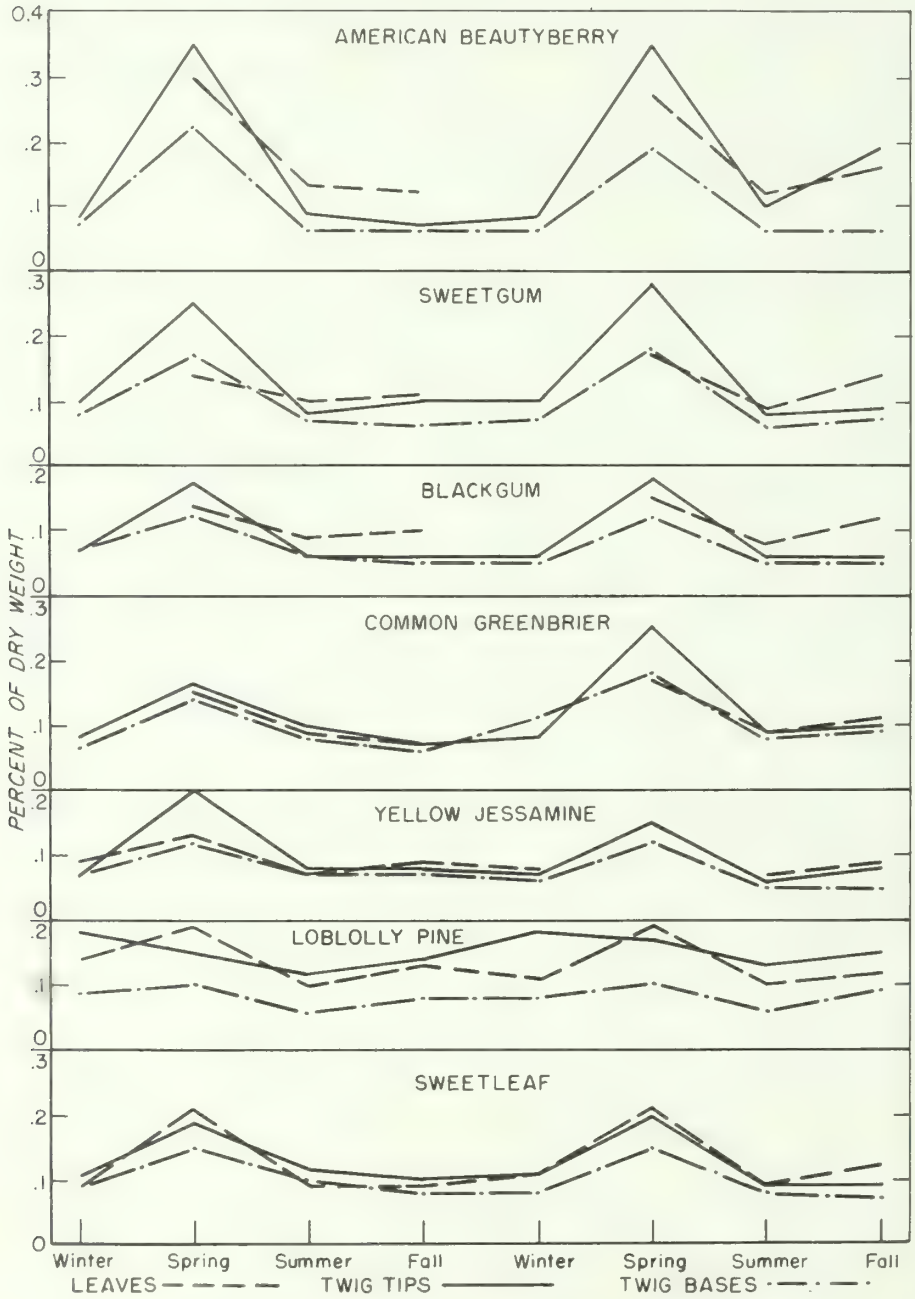

Figure 8.—*Seasonal phosphorus contents of plant parts, 1960-1961.*

In the spring, twig tips of most species provided more phosphorus than leaves, and leaves provided more than twig bases. With growth maturation, leaves generally contained about as much, and often more, phosphorus than twigs, especially twig bases.

Twig tips of evergreens were a better source of phosphorus than twig bases at all seasons, but in deciduous species, tips were superior to bases only in the spring.

Dietary phosphorus is extremely important to deer. It is essential for bone development, growth, reproduction, and lactation.

The dietary requirements for deer, while not precisely known, appear to be about 0.56 percent of the daily dry-matter intake for optimum growth, and about 0.25 to 0.30 percent for maintenance (*20*).

All species in the present study were low in phosphorus, which is characteristic of southern forages (*3, 4, 5, 12, 18*). Values of 0.56-percent phosphorus were never provided by either leaves or twigs. Only in spring did leaves and twig tips of American beautyberry and twig tips of sweetgum provide enough for deer maintenance.

Calcium-Phosphorus Ratio

Calcium and phosphorus utilization appear to be closely interrelated (*20*). A deficiency of one mineral seems to be better tolerated if the other is present in adequate amounts. Phosphorus, however, is assimilated at a reduced rate when it occurs in the presence of large amounts of calcium or vice versa (*2, 21, 27, 28, 29*). Hence, the ratio of calcium to phosphorus in feeds is significant. For livestock forage, the most desirable ratio is from 2:1 to 1:2.

Importance of the Ca:P ratio is reduced and efficiency of utilization of the elements is increased by the presence of sufficient vitamin D (*21*). A ratio higher than 2:1 can, therefore, be tolerated without ill effects. According to Mitchell and McClure (*22*), a ratio as high as 5.5:1 may be acceptable. Biswell *et al.* (*2*) concluded that the ratio probably never gets out of proportion for cattle exposed to abundant sunshine for vitamin D production.

In the present data the Ca:P ratios were generally lower in spring than at other seasons. In spring, ratios in leaves ranged from 1.3:1 for pine to 5.3:1 for greenbrier. In twig tips they varied from 1.4:1 in yellow jessamine to 5.0:1 in sweetgum. In basal twigs, the ratio ranged from 1.3:1 in greenbrier to 8.6:1 in sweetgum.

After tissue maturation, Ca:P ratios usually widened considerably and varied little seasonally from summer to winter. During this period, the most favorable ratio in leaves, 2.3:1, was in

pine needles. The most unfavorable was in leaves of greenbrier in summer–15.7:1. Ratios in twigs ranged from 2.2:1 in summer tips of pine stems to 29.5:1 in stem bases of sweetgum.

Ca:P ratios in twig tips tended to be slightly more desirable than those in leaves at all seasons. Those of twig bases were generally the least desirable.

SUMMARY

Most changes in chemical makeup of the seven species were associated with tissue growth and maturation. In spring, leaves and twigs were most succulent, and their dry-matter fraction was highest in protein, ash, and phosphorus, and lowest in crude fiber. By midsummer, contents of moisture, protein, ash, and phosphorus had declined appreciably, while crude-fiber content increased. Tissues, especially twigs, remained fibrous, and nutrient levels usually varied little from summer through winter. The ether-extract content was low and fluctuated little seasonally. Nitrogen-free extract and calcium levels fluctuated sporadically and varied considerably by species. Calcium content tended to increase as tissues matured.

Over most of the year, leaf tissues were more succulent, higher in protein, crude fat, NFE, ash, calcium, and phosphorus, and considerably lower in crude fiber than twigs. The superior nutrient quality of leaves emphasizes the importance of broad-leaved evergreens on southern deer ranges. Leaves of these species are more nutritious than fibrous twigs in late fall and winter, when the quality of other forage is relatively low. Twig tips contained a higher percentage of nutrients than slightly older portions of stems.

Although the nutritional requirements of southern deer are unknown, it appeared that sufficient protein for animal maintenance, and in some instances for body growth, was present in leaves and twigs in spring. After tissues matured in early summer, only leaves contained protein levels believed necessary for deer maintenance. Calcium appeared to be adequate in most plant parts and species at all seasons. Phosphorus was generally deficient throughout the year.

LITERATURE CITED

1. Association of Official Agricultural Chemists.
1955. Official methods of analysis. Ed. 8, 1008 pp. Wash., D.C.: J. Assoc. Offic. Agr. Chem.

2. Biswell, H. H., Collins, R. W., Foster, J. E., and Boggess, T. S., Jr.
1945. Native forage plants. N. C. Agr. Exp. Sta. Bull. 353, 27 pp.

3. Blair, R. M., and Halls, L. K.
1968. Growth and forage quality of four southern browse species. Southeast. Assoc. Game and Fish Comm. 21st Annu. Conf. Proc. 1967: 57-62.

4. Campbell, R. S., and Cassady, J. T.
1951. Grazing values for cattle on pine forest ranges in Louisiana. La. Agr. Exp. Sta. Bull. 452, 31 pp.

5. Campbell, R. S., Epps, E. A., Moreland, C. C., and others.
1954. Nutritive values of native plants on forest range in central Louisiana. La. Agr. Exp. Sta. Bull. 488, 18 pp.

6. Cook, C. W., and Harris, L. E.
1950. The nutritive value of range forage as affected by vegetation type, site, and stage of maturity. Utah Agr. Exp. Sta. Bull. 344, 45 pp.

7. Dietz, D. R., Udall, R. H., Shepherd, H. R., and Yeager, L. E.
1959. Seasonal progression in chemical content of five key browse species in Colorado. Soc. Amer. Forest. Proc. 1958: 117-122.

8. Dietz, D. R., Udall, R. H., and Yeager, L. E.
1962. Chemical composition and digestibility by mule deer of selected forage species, Cache La Poudre Range, Colorado. Colo. Game and Fish Dep. Tech. Pub. 14, 89 pp.

9. Duncan, D. B.
1955. Multiple range and multiple F tests. Biometrics 11: 1-42.

0. Dyke, R. A.
1941. Climate of Louisiana. *In* Climate and man, pp. 894-903. USDA Yearbook.

1. French, C. E., McEwen, L. C., Magruder, N. D., and others.
1955. Nutritional requirements of white-tailed deer for growth and antler development. Penn. Agr. Exp. Sta. Bull. 600, 50 pp.

12. Halls, L. K., Hale, O. M., and Knox, F. E.
1957. Seasonal variation in grazing use, nutritive content, and digestibility of wiregrass forage. Ga. Agr. Exp. Sta. Tech. Bull. (n.s.) 11, 28 pp.

13. Halls, L. K., and Alcaniz, R.
1965. Seasonal twig growth of southern browse plants. USDA Forest Serv. Res. Note SO-23, 5 pp. South. Forest Exp. Sta., New Orleans, La.

14. Harter, H. L.
1960. Critical values for Duncan's new multiple range test. Biometrics 16: 671-685.

15. Hundley, L. R.
1959. Available nutrients in selected deer-browse species growing on different soils. J. Wildlife Manage. 23: 81-90.

16. Kramer, P. J., and Kozlowski, T. T.
1960. Physiology of trees. 642 pp. N. Y.: McGraw-Hill Book Co., Inc.

17. Lay, D. W.
1957. Browse quality and the effects of prescribed burning on southern pine forests. J. Forest. 55: 342-347.

18. Lay, D. W.
1957. Some nutrition problems of deer in the southern pine type. Southeast. Assoc. Game and Fish Comm. 10th Annu. Conf. Proc. 1956: 53-58.

19. Long, T. A., Cowan, R. L., Wolfe, C. W., and others.
1959. Effect of seasonal feed restriction on antler development of white-tailed deer. Penn. Agr. Exp. Sta. Progr. Rep. 209, 11 pp.

20. Magruder, N. D., French, C. E., McEwen, L. C., and Swift, R. W.
1957. Nutritional requirements of white-tailed deer for growth and antler development. II. Experimental results of the third year. Penn. Agr. Exp. Sta. Bull. 628, 21 pp.

21. Maynard, L. A., and Loosli, J. K.
1956. Animal nutrition. Ed. 4, 484 pp. N. Y.: McGraw-Hill book Co., Inc.

22. Mitchell, H. H., and McClure, F. J.
1937. Mineral nutrition of farm animals. Nat. Res. Counc. Bull. 99, 135 pp.

23. Morrison, F. B.
1957. Feeds and feeding. Ed. 22, 1165 pp. Ithaca: Morrison Publishing Co.

24. Murneek, A. E.
1942. Quantitative distribution of nitrogen and carbohydrates in apple trees. Mo. Agr. Exp. Sta. Res. Bull. 348, 28 pp.

25. Short, H. L.
1966. Effects of cellulose levels on the apparent digestibility of feeds eaten by mule deer. J. Wildlife Manage. 30: 163-167.

26. Short, H. L., Dietz, D. R., and Remmenga, E. E.
1966. Selected nutrients in mule deer browse plants. Ecology 47: 222-229.

27. Smith, F. H., Beeson, K. C., and Price, W. E.
1956. Chemical composition of herbage browsed by deer in two wildlife management areas. J. Wildlife Manage. 20: 359-367.

28. Stoddart, L. A., and Greaves, J. E.
1942. The composition of summer range plants in Utah. Utah Agr. Exp. Sta. Bull. 305, 22 pp.

29. Swank, W. G.
1956. Protein and phosphorus content of browse plants as an influence on southwestern deer herd levels. N. Amer. Wildlife Conf. Trans. 21: 141-158.

30. Taber, R. D.
1956. Deer nutrition and population dynamics in the north coast range of California. N. Amer. Wildlife Conf. Trans. 21: 159-172.

31. Van Soest, P. J., and Moore, L. A.
1966. New chemical methods for analysis of forages for the purpose of predicting nutritive value. Ninth Int. Grassland Congr. Proc. 1965: 783-789. Sao Paulo, Brazil.

32. Van Soest, P. J., and Wine, R. H.
1967. Use of detergents in the analysis of fibrous feeds. IV. Determination of plant cell-wall constituents. J. Assoc. Offic. Anal. Chem. 50: 50-55.

Table 1.—*Chemical composition of American beautyberry* (Callicarpa americana)

Season	Plant fraction	Dry matter	Crude protein	Ether extract	Crude fiber	NFE	Ash	Calcium	Phosphorus	Ca:P
		Pct. of fresh wt.	*Percent of ovendry weight*							*Ratio*
Spring	Leaves	25.9	22.4*[1] a[2]	5.5*[1] b[2]	12.4	52.4	7.4	0.90*[1] c[2]	0.28+[1] a[2]	3.2:1
	Twig tips	16.8	19.4+ a	3.3*,+ a	20.0	47.8	9.6	.74*,+ a	.35* a	2.1:1
	Twig bases	18.5	12.0# a	2.1+ a	34.6	42.6	8.6	.66+ a	.20# a	3.3:1
Summer	Leaves	32.6	12.1* b	6.8* a,b	17.2	56.2	7.6	1.15* b	.13* b	8.8:1
	Twig tips	41.8	6.4+ b	1.8+ a	35.0	52.6	4.1	.63+ a	.09+ b	7.0:1
	Twig bases	45.7	4.3# b	1.8+ a	42.0	50.0	2.6	.55+ a	.06# b	9.2:1
Fall	Leaves	34.0	10.8* b	7.9* a	14.2	59.7	7.4	1.37* a	.14* b	9.8:1
	Twig tips	49.2	5.4+ b	1.7+ a	36.4	53.0	3.6	.65+ a	.08+ b	8.1:1
	Twig bases	51.8	4.1+ b	1.2+ a	43.0	48.8	2.8	.58+ a	.06+ b	9.7:1
Winter	Leaves	. . .	. . .	. .	. . .	. . .	. . .	. . .	. . .	. . .
	Twig tips	58.2	6.2*	2.2*	36.2	51.7	3.8	.67*	.08+	8.4:1
	Twig bases	57.9	4.9+	1.8*	44.3	45.6	3.4	.60*	.07*	8.6:1

[1]Within a season, means followed by the same symbol do not differ significantly ($P > 0.05$). For example, in spring, summer, and fall, leaf tissues contained more protein than twigs.

[2]For individual plant fractions, means followed by the same letter do not differ significantly ($P > 0.05$) between seasons. For example, leaves contained significantly more protein in spring than in summer and fall, but leaf protein levels in summer and fall did not differ significantly.

Table 2.–*Chemical composition of sweetgum* (Liquidambar styraciflua)

Season	Plant fraction	Dry matter	Crude protein	Ether extract	Crude fiber	NFE	Ash	Calcium	Phosphorus	Ca:P
		Pct. of fresh wt.	- - - - - - - - - - - - - - - - *Percent of ovendry weight* - - - - - - - - - - - - - - - -							*Ratio*
Spring	Leaves	29.8	11.8*[1] a[2]	3.0*[1] a[2]	9.8	70.6	5.0	0.78+[1] b[2]	0.16+[1] a[2]	4.9:1
	Twig tips	21.4	10.9* a	3.2* a	11.4	67.0	7.4	1.29* b	.26* a	5.0:1
	Twig bases	20.0	7.7+ a	2.4* a	20.1	63.0	6.8	1.51* a	.17+ a	8.9:1
Summer	Leaves	36.4	9.0* b	2.2* a	10.0	73.2	5.5	1.17+ a	.10* b	11.7:1
	Twig tips	36.6	4.1+ b	2.7* a	25.4	63.0	4.8	1.72* a	.08*,+ b	21.5:1
	Twig bases	38.2	2.7+ b	1.6* a	33.8	58.1	3.9	1.38+ a	.06+ b	23.0:1
Fall	Leaves	35.6	8.9* b	2.3* a	11.0	70.3	7.5	1.15# a	.12* b	9.6:1
	Twig tips	41.2	4.0+ b	2.7* a	24.9	62.5	6.0	1.87* a	.09*,+ b	20.8:1
	Twig bases	43.2	2.9+ b	1.2* a	33.4	57.4	5.0	1.59+ a	.07+ b	22.7:1
Winter	Leaves	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
	Twig tips	43.8	5.5*	2.6* a	24.2	61.3	6.3	2.12*	.10*	21.2:1
	Twig bases	44.4	4.4*	1.9* a	32.0	56.5	5.2	1.61*	.08*	20.1:1

[1]Within a season, means followed by the same symbol do not differ significantly ($P > 0.05$).

[2]For individual plant fractions, means followed by the same letter do not differ significantly ($P > 0.05$) between seasons.

Table 3.- *Chemical composition of blackgum* (Nyssa sylvatica)

Season	Plant fraction	Dry matter	Crude protein	Ether extract	Crude fiber	NFE	Ash	Calcium	Phosphorus	Ca:P
		Pct. of fresh wt.	*Percent of ovendry weight*							*Ratio*
Spring	Leaves	29.2	11.9*[1] a[2]	2.6*[1] b[2]	11.7	69.0	4.8	0.51+[1] b[2]	0.15+[1] a[2]	3.4:1
	Twig tips	19.8	8.5+ a	2.6* a	20.4	60.6	7.8	.78* b	.18* a	4.3:1
	Twig bases	23.2	5.7# a	1.8* a	35.4	51.0	6.2	.78* a	.12# a	6.5:1
Summer	Leaves	37.4	9.2* b	3.8* a,b	14.6	67.9	4.2	.80+ a	.09* c	8.9:1
	Twig tips	45.6	3.4+ b	2.4* a	35.0	56.0	3.2	1.10* a	.06+ b	16.8:1
	Twig bases	48.2	2.6+ b	2.3* a	43.6	49.2	2.7	.81+ a	.06# b	13.5:1
Fall	Leaves	42.4	8.9* b	5.2* a	14.2	66.7	4.8	.83*,+ a	.11* b	7.5:1
	Twig tips	52.6	3.5+ b	2.3+ a	36.4	54.7	3.0	.94* a	.06+ b	15.7:1
	Twig bases	53.8	2.9+ b	2.2+ a	43.6	49.2	2.4	.77+ a	.05+ b	15.4:1
Winter	Leaves	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
	Twig tips	48.2	4.2*	3.0*	36.6	52.2	4.1	1.23*	.07*	17.6:1
	Twig bases	49.3	3.3+	2.2*	44.0	47.5	3.0	.94+	.06*	15.7:1

[1]Within a season, means followed by the same symbol do not differ significantly ($P > 0.05$).

[2]For individual plant fractions, means followed by the same letter do not differ significantly ($P > 0.05$) between seasons.

Table 4.–*Chemical composition of common greenbrier* (Smilax rotundifolia)

Season	Plant fraction	Dry matter	Crude protein	Ether extract	Crude fiber	NFE	Ash	Calcium	Phosphorus	Ca:P
		Pct. of fresh wt.	*Percent of ovendry weight*							*Ratio*
Spring	Leaves	24.9	12.7*[1] a[2]	4.1*[1] b[2]	20.8	57.4	5.0	0.82*[1] b[2]	0.16*[1] a[2]	5.1:1
	Twig tips	25.0	9.8+ a	1.9+ a	43.6	39.6	5.0	.33+ a	.20* a	1.6:1
	Twig bases	25.0	7.5# a	1.6+ a	46.4	40.3	4.1	.22+ a	.16* a	1.4:1
Summer	Leaves	34.5	10.1* b	4.8* b	20.2	60.6	4.5	1.30* a	.09* b	14.4:1
	Twig tips	41.7	4.8+ b	1.4+ a	52.0	39.1	2.6	.26+ a	.09* b	2.9:1
	Twig bases	40.8	4.2+ b	1.2+ a	53.0	39.2	2.5	.32+ a	.08* b	4.0:1
Fall	Leaves	36.2	9.2* b	6.1* a	19.8	59.6	5.2	1.36* a	.09* b	15.1:1
	Twig tips	44.8	5.3+ b	1.3+ a	53.4	37.4	2.6	.30+ a	.08* b	3.8:1
	Twig bases	45.0	4.6+ b	1.2+ a	55.0	36.8	2.4	.27+ a	.07* b	3.8:1
Winter	Leaves	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
	Twig tips	47.8	7.0*	1.9*	50.3	37.4	3.4	.38*	.08*	4.8:1
	Twig bases	46.9	5.9*	1.9*	50.6	38.6	3.1	.30*	.08*	3.8:1

[1]Within a season, means followed by the same symbol do not differ significantly ($P > 0.05$).

[2]For individual plant fractions, means followed by the same letter do not differ significantly ($P > 0.05$) between seasons.

Table 5.–*Chemical composition of yellow jessamine* (Gelsemium sempervirens)

Season	Plant fraction	Dry matter	Crude protein	Ether extract	Crude fiber	NFE	Ash	Calcium	Phosphorus	Ca:P
		Pct. of fresh wt.	*Percent of ovendry weight*							*Ratio*
Spring	Leaves	30.0	11.8*[1] a[2]	6.9*[1] b[2]	12.2	64.8	4.2	0.37*[1] d[2]	0.12+[1] a[2]	3.1:1
	Twig tips	29.5	8.8+ a	5.0+ a	31.2	50.3	4.6	.28+ d	.17* a	1.6:1
	Twig bases	31.0	6.8# a	3.3# a	40.8	45.5	3.6	.21# c	.12+ a	1.8:1
Summer	Leaves	36.8	9.2* b	8.1* a,b	14.5	64.2	4.0	.49* c	.08* c	6.1:1
	Twig tips	48.2	4.2+ b	3.3+ b	38.1	51.8	2.6	.35+ c	.07* b	5.0:1
	Twig bases	45.8	3.8+ b	2.4+ a	42.6	49.0	2.2	.23# c	.06+ b	3.8:1
Fall	Leaves	38.2	9.5* b	9.8* a	14.0	62.0	4.7	.56* b	.09* b	6.2:1
	Twig tips	44.3	4.6+ b	3.6+ a,b	38.0	51.3	2.5	.42+ b	.08+ b	5.2:1
	Twig bases	46.2	3.6+ b	2.6+ a	45.0	46.6	2.2	.29# b	.06# b	4.8:1
Winter	Leaves	42.1	9.3* b	9.4* a	12.8	64.8	3.6	.61* a	.09* b	6.8:1
	Twig tips	53.6	5.3+ b	3.6+ a,b	37.4	51.1	2.5	.47+ a	.07+ b	6.7:1
	Twig bases	52.7	4.3+ b	2.8+ a	41.8	48.7	2.4	.38# a	.06# b	6.3:1

[1]Within a season, means followed by the same symbol do not differ significantly ($P > 0.05$).

[2]For individual plant fractions, means followed by the same letter do not differ significantly ($P > 0.05$) between seasons.

Table 6.--*Chemical composition of young loblolly pine* (Pinus taeda)

Season	Plant fraction	Dry matter	Crude protein	Ether extract	Crude fiber	NFE	Ash	Calcium	Phosphorus	Ca:P
		Pct. of fresh wt.	*Percent of ovendry weight*							*Ratio*
Spring	Leaves	26.4	10.7*[1] a[2]	4.1+[1] c[2]	26.0	55.0	4.2	0.28*[1] b[2]	0.19*[1] a[2]	1.5:1
	Twig tips	20.8	7.7+ b	6.5* b	24.0	57.6	4.2	.29* b	.16+ b	1.8:1
	Twig bases	22.0	4.8# a	5.5*,+ b	32.4	54.0	3.3	.23* b	.10# a	2.3:1
Summer	Leaves	31.8	7.6* c	5.8* b,c	27.0	57.0	2.6	.33* b	.10+ c	3.3:1
	Twig tips	33.0	5.0+ c	6.9* b	33.8	51.4	2.8	.28* b	.13* d	2.2:1
	Twig bases	34.4	2.8# b	5.2* b	43.4	51.6	2.0	.28* a,b	.06# c	4.7:1
Fall	Leaves	33.5	8.2* b,c	7.4* b	26.7	54.9	2.8	.31* b	.12+ b	2.6:1
	Twig tips	34.8	5.7+ c	6.8* b	36.9	47.7	2.9	.35* a,b	.14* c	2.5:1
	Twig bases	34.3	3.2# b	4.4+ b	47.2	43.2	2.0	.31* a,b	.08# b	3.9:1
Winter	Leaves	41.4	8.9* b	10.4+ a	21.4	56.4	2.8	.45* a	.12+ b	3.8:1
	Twig tips	44.2	8.8* a	12.7* a	26.6	48.6	3.4	.42* a	.18* a	2.3:1
	Twig bases	43.5	4.7+ a	9.7+ a	38.6	44.8	2.2	.35* a	.08# b	4.4:1

[1]Within a season, means followed by the same symbol do not differ significantly ($P > 0.05$).

[2]For individual plant fractions, means followed by the same letter do not differ significantly ($P > 0.05$) between seasons.

Table 7.—*Chemical composition of common sweetleaf* (Symplocos tinctoria)

Season	Plant fraction	Dry matter	Crude protein	Ether extract	Crude fiber	NFE	Ash	Calcium	Phosphorus	Ca:P
		Pct. of fresh wt.	*Percent of ovendry weight*							*Ratio*
Spring	Leaves	19.2	16.1*[1] a[2]	2.8*[1] c[2]	16.4	53.6	11.2	0.93*[1] b[2]	0.21*[1] a[2]	4.4:1
	Twig tips	16.1	11.1+ a	1.8* a	25.9	50.2	11.0	.80* b	.20+ a	4.0:1
	Twig bases	18.2	7.7# a	1.8* a	36.2	46.0	8.4	.51+ b	.15# a	3.4:1
Summer	Leaves	25.8	11.7* b	4.2* b	13.6	59.5	11.0	1.28* a	.09+ c	14.2:1
	Twig tips	31.6	5.3+ b	1.1+ a	32.2	53.9	7.5	1.35* a	.11* c	12.3:1
	Twig bases	33.6	4.1# b	.9+ a	40.8	49.0	5.2	.75+ a,b	.09+ b	8.3:1
Fall	Leaves	27.6	11.2* b	6.3* a	13.2	59.0	10.2	1.16+ a,b	.10* b	11.6:1
	Twig tips	35.6	5.2+ b	1.6+ a	28.6	56.8	7.8	1.61* a	.10* d	16.1:1
	Twig bases	37.8	4.0# b	1.0+ a	40.7	49.4	5.0	.94+ a	.08+ c	11.8:1
Winter	Leaves	31.4	10.1* c	6.1* a	11.2	62.4	10.2	.98+ b	.10+ b	9.8:1
	Twig tips	39.0	5.9+ b	1.8+ a	28.6	55.4	8.4	1.41* a	.11* b	12.8:1
	Twig bases	40.4	4.8# b	1.4+ a	41.0	47.0	5.6	.88+ a	.09# b	9.8:1

[1]Within a season, means followed by the same symbol do not differ significantly ($P > 0.05$).

[2]For individual plant fractions, means followed by the same letter do not differ significantly ($P > 0.05$) between seasons.

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Abstract

Specimens of earlywood and latewood of Pinus taeda *L. were excised so that length along the grain was 3 inches and thickness was 0.1 inch. These specimens were cut orthogonally—as with a carpenter's plane—in the three major directions. Cutting velocity was 2 inches per minute.*

When cutting was in the planing (90-0) direction, thin chips, intermediate to high moisture content, rake angles of 5 and 15° favored formation of the Franz Type II chip and accompanying good surfaces.

In the 0-90 direction, a knife with 70° rake angle cut the best veneer; wood cut saturated yielded the highest proportion of continuous veneer, although saturated earlywood developed some compression tearing.

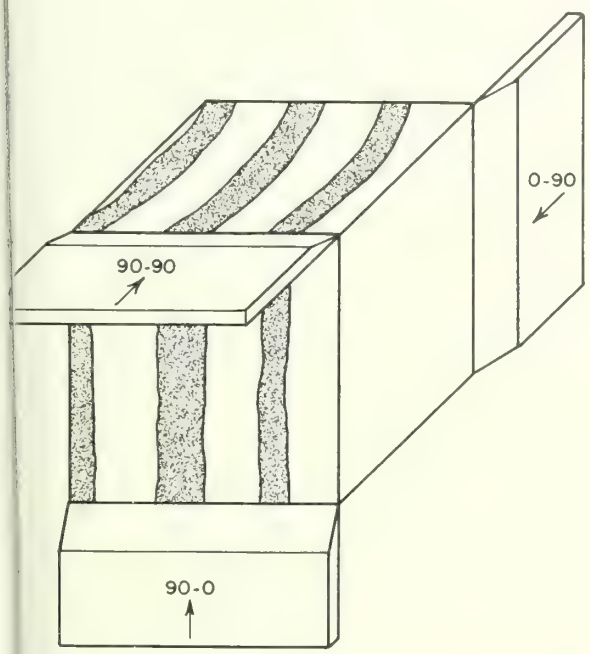
When cutting was across the grain (90-90 direction), McKenzie Type I chips were formed and the best surfaces were achieved with a knife having 45° rake angle cutting saturated wood; earlywood was more difficult to surface smoothly than latewood.

For each cutting direction, regression equations were developed to state average cutting forces (normal and parallel) in terms of rake angle, depth of cut, specific gravity, and moisture content.

Tool Forces and Chip Formation in Orthogonal Cutting of Loblolly Pine

The objective of the study reported in this aper was to determine chip types and tool rces typical of loblolly pine earlywood and tewood machined orthogonally.

Orthogonal cutting is the machining pro- ss in which the cutting edge is perpendicular the relative motion of tool and workpiece. e surface generated is a plane parallel to the iginal work surface. A carpenter's plane cuts thogonally, as does a bandsaw. Rotary peeling veneer approximates orthogonal cutting. A o-number notation used by McKenzie (1961) useful in describing the machining situation g. 1).



re 1.—*Designation of the three major machining directions. The first number is the angle the cutting edge makes with the grain; the second is the angle between cutter movement and grain.*

The world literature on orthogonal cutting is digested in Koch's (1964) text and in the wood-machining reviews by Koch and McMillin (1966a, 1966b) and Koch (1968). The only data specific to southern pine are from studies of veneer cutting. Considerable information on this topic has been issued by the USDA Forest Products Laboratory (Lutz 1964, 1967; Lutz *et al.* 1962, 1966, 1967, 1969; Lutz and Patzer 1966; Peters *et al.* 1969). Cade and Choong (1969) also have investigated the rotary peeling of southern pine venner.

SCOPE

Because of wide latewood bands, the wood of loblolly pine alternately displays the machining characteristics of two distinct materials, i.e., earlywood and latewood. For this reason, and also because of the difficulty in collecting wholewood specimens statistically representative of the entire species, wood of each cell type was studied separately. Interpolation of data between these extremes should permit estimation of cutting forces in southern pine of intermediate densities, though it should be recognized that small excised specimens of earlywood and latewood may machine differently than the same wood interlayered *in situ.*

For each of the three primary directions (fig. 1), chip formation was studied and photographed; cutting forces were recorded at a variety of rake angles, depths of cut, and moisture contents. Cutting speed was constant at 2 inches per minute. The main study was factorial with five factors:

Cutting direction

90-0 (planing)
0-90 (veneer direction)
90-90 (crosscut)

Rake angle
(clearance angle constant at 15°)

25°
35°

Depth of cut (inch)

0.015
.030
.045
.060

Moisture content (percent)

7
15.5
Saturated

Type of cell

Earlywood
Latewood

Replications: 5

Because the practical range of rake angles differs for each cutting direction, some additional knives were studied:

In the veneer direction (0-90) a special veneer knife with 70° rake angle (20° sharpness angle and no clearance angle) was used in addition to knives with 25, 35, and 45° rakes. Other factors remained the same.

In the crosscut direction (90-90) a knife with 45° rake angle and 15° clearance angle was added.

In the planing direction (90-0) knives with rake angles of 5 and 15° were added.

In all, 1,320 observations were made, of which 720 were in the main experiment (table 1).

Table 1. — *Number of observations for various cutting directions*

Cutting direction	Cell types	Rake angle	Depth of cut	Moisture content	Replication	Total
0-90	2	4	4	3	5	480
90-90	2	3	4	3	5	360
90-0	2	4	4	3	5	480
						1,320

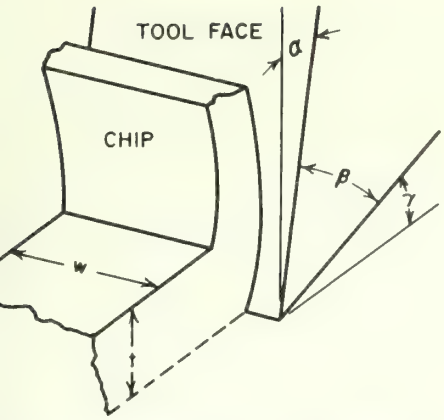
Figure 2 illustrates nomenclature of orthogonal cutting.

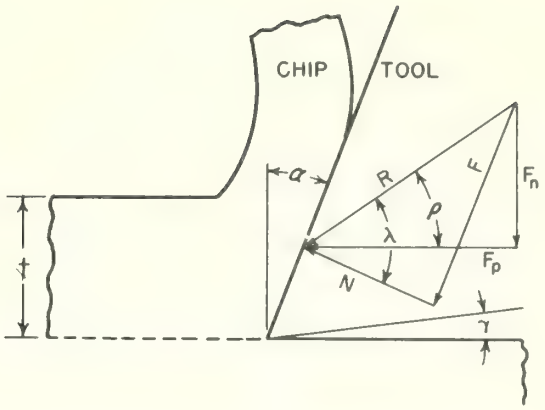
PROCEDURE

Material was obtained from loblolly pine trees cut near Effie, Louisiana, by the Roy O. Martin Lumber Company. Cross-sectional disks measuring approximately 4 inches along the grain were taken from logs exhibiting fast growth and wide bands of latewood. As an aid to specimen preparation, sampling was limited to logs at least 15 inches in diameter. Compression wood and wood below breast height in the standing tree were avoided. The disks were coated with antistain chemical and conditioned to 9-percent equilibrium moisture content.

Specimens.—Each disk was split into blocks containing the band of earlywood or latewood to be used. The identity of each growth ring was maintained. The bark and all wood between the bark and the selected growth ring were removed with a hand ax and chisel to expose a tangential surface. After trimming, each piece was placed against a belt sander for light sanding. The resulting flat reference surface aided in machining a rectangular block with the growth ring (earlywood or latewood) exposed on one side (fig. 3). Since the block had been split off the disk, it was relatively simple to make specimens with the grain parallel to the sides.

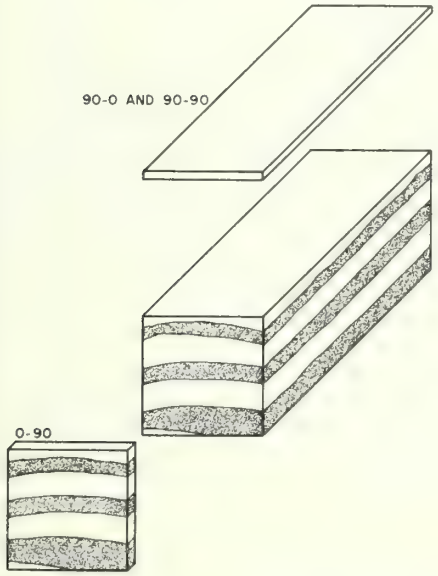
From the master blocks it was possible to prepare specimens for all cutting directions. In veneer cutting, wafers approximately 0.1-in. wide were crosscut (fig. 4, 0-90). For the planing and crosscutting directions, specimens 0.1-in. wide were prepared by ripping the earlywood or latewood band off the rectangular block. Specimens were brought to equilibrium moisture content.





ıre 2.—*Nomenclature in orthogonal cutting.*

- α — *Rake angle: angle between the tool face and a plane perpendicular to the direction of tool travel.*
- β — *Sharpness angle: angle between the tool face and back.*
- γ — *Clearance angle: angle between the back of the tool and the work surface behind the tool.*
- t — *Thickness of chip before removal from the workpiece.*
- w — *Width of undeformed chip.*
- F_n — *Normal tool force: force component acting perpendicular to parallel tool force and perpendicular to the surface generated.*
- F_p — *Parallel tool force: force component acting parallel to tool motion in workpiece, i.e., parallel to cut surface.*
- R — *Resultant tool force: the resultant of normal and parallel tool force components.*
- ρ — *Angle of tool force resultant: the angle whose tangent is equal to the normal tool force divided by the parallel tool force.*
- F — *Friction force: force component acting along the interface between tool and chip.*
- N — *Normal to the friction force: force component acting normal to tool face.*
- λ — *Angle between resultant tool force and the normal frictional force; the angle whose tangent is equal to the friction force divided by the normal friction force.*



ıre 3.—*Sketch of master block, showing how specimens were prepared.*

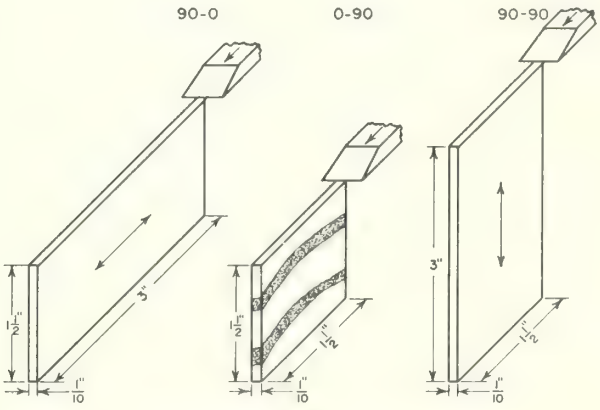


Figure 4.—*Specimens for orthogonal cutting.*

All specimens for a given replication came from the same growth ring and were considered matched, even though they sometimes were from opposite sides of the disk. There were five replications; therefore wood from five different rings was studied.

Specific gravity—on the basis of ovendry weight and ovendry volume—was determined on six specimens randomly selected from each replication. Thus there were 30 determinations for latewood and 30 for earlywood. A mercury volumeter was used for measuring the ovendry volume.

Dynamometer.—A two-component tool dynamometer (Franz 1958) was used (fig. 5) to measure cutting forces. The parallel and normal forces were simultaneously and continuously recorded on a two-channel recorder. Pen deflections on the recorder were calibrated by hanging known weights on the dynamometer-mounted tool point.

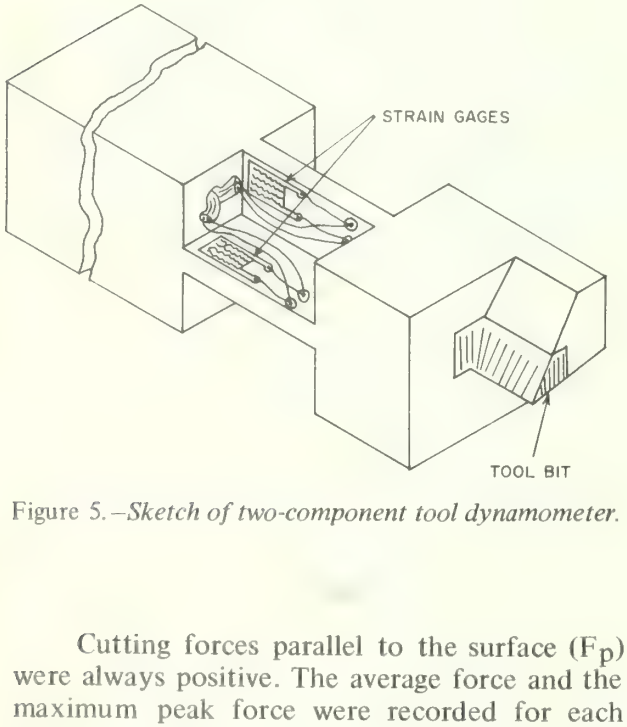


Figure 5.—*Sketch of two-component tool dynamometer.*

Cutting forces parallel to the surface (F_p) were always positive. The average force and the maximum peak force were recorded for each run. The average force was determined by making areas above and below the average line equal.

Cutting forces normal to the surface (F_n) were sometimes positive (the knife forced the workpiece away) and sometimes negative (the knife tended to lift the workpiece). The average, minimum, and maximum were recorded with appropriate algebraic sign; for example, the minimum force might have been −5 pounds, the maximum −1 pound, and the average (based on areas) intermediate.

Width of each specimen was measured with a micrometer so that cutting forces could be adjusted to a standard 0.1-inch width of cut. It is well established that cutting force is directly proportional to width of cut.

Cutting procedures.—Five cutters had rake angles of 5, 15, 25, 35, and 45° (with clearance angle constant at 15°). A sixth knife, used only when cutting veneer, had a rake angle of 70°, with zero clearance angle. The face of each bit was approximately 5/16-inch square; grinding marks were perpendicular to the cutting edge. Edges were examined under a microscope to make sure nicks were absent.

The dynamometer was mounted in a fixture bolted to the bed plate of an Instron testing machine. The workpiece holder was carried in a swivel-mounted traversing vise attached to the crossarm of the Instron. The traversing vise was adjusted for each depth of cut. Crosshead traverse determined cutting speed, which was held constant at 2 inches per minute.

Humidity in the testing room was controlled to give an equilibrium moisture content of either 7 or 15.5 percent. The saturated specimens were kept wetted during test.

Specimens were machined in random order. Cutting procedure varied. In the veneer-cutting direction a smoothing cut was first made with the knife having a 70° rake angle, after which (in most cases) a single cut was taken for record; the specimen was then discarded. For 90-0, a smoothing cut was made in the planing direction before the initial cut—and, when roughness made it necessary, before each succeeding cut in the series of four depths; cuts were made in sequence from 0.015 to 0.060 inch. In the 90-0 direction an initial smoothing cut was unnecessary, as the sawn end of the block was sufficiently smooth; after each cut, the surface was trimmed smooth again.

Chip formation was viewed through a microscope at 30X magnification. Representative chips were photographed.

Average specific gravity, as determined from ovendry weight and ovendry volume, was found to be:

	Earlywood	Latewood
Average	0.34	0.85
Range	0.29-0.42	0.77-0.96
Standard deviation	0.036	0.046

PARALLEL TO GRAIN: 90-0 DIRECTION

As recorded by Koch (1955, p. 261; 1956, p. 397) and enumerated by Franz (1958), three basic chip types are observable when wood is machined parallel to the grain in the 90-0 direction.

Type I chips are formed when cutting conditions are such that the wood splits ahead of the tool by cleavage until it fails in bending as a cantilever beam, as illustrated in figure 6a. Machining of saturated specimens of both earlywood and latewood, however, somtimes results in a peeling action rather than an abrupt breaking (fig. 6b). Factors leading to formation of Type I chips are:

Low resistance in cleavage in combination with high stiffness and strength in bending.

Deep cuts (Type I chips can form with any depth of cut, depending on the other factors)

Large rake angles (25° and more)

Low coefficient of friction between chip and tool face

Low moisture content in the wood.

The Type I chip leaves a surface that exhibits chipped grain, i.e., the splitting that occurs ahead of the cutting edge frequently runs below the plane generated by the path of the cutting edge. The amount of roughness depends upon the depth to which the cleavage runs into the wood. Power consumed by a knife forming

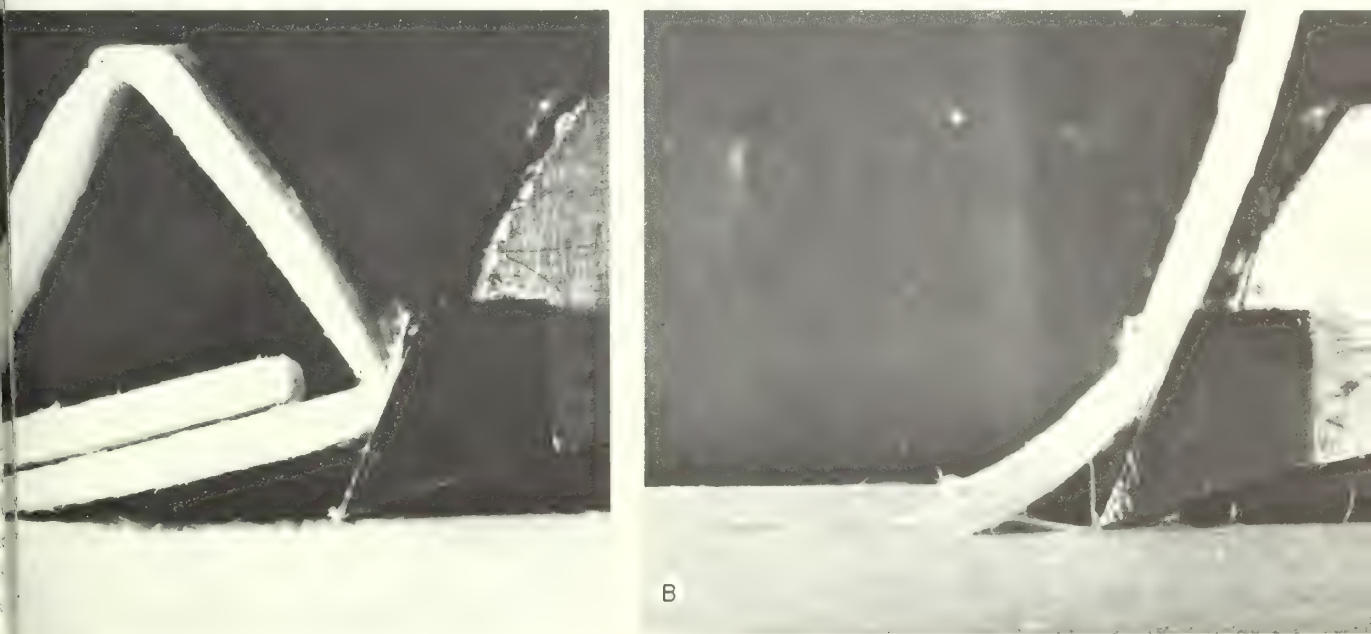


Figure 6.—*Franz Type I chips from 0.045-inch cuts in 90-0 direction, 25° rake angle. A: In loblolly pine earlywood at 7-percent moisture content. B: In saturated loblolly pine latewood.*

Type I chips is low, because wood fails relatively easily in tension perpendicular to the grain, and the knife severs few fibers. Because it is seldom cutting, the knife edge dulls slowly.

With rake angles of 25 and 35° the normal cutting force (F_N) was negative at all depths of cut for all moisture contents (fig. 7), and Type I chips were formed.

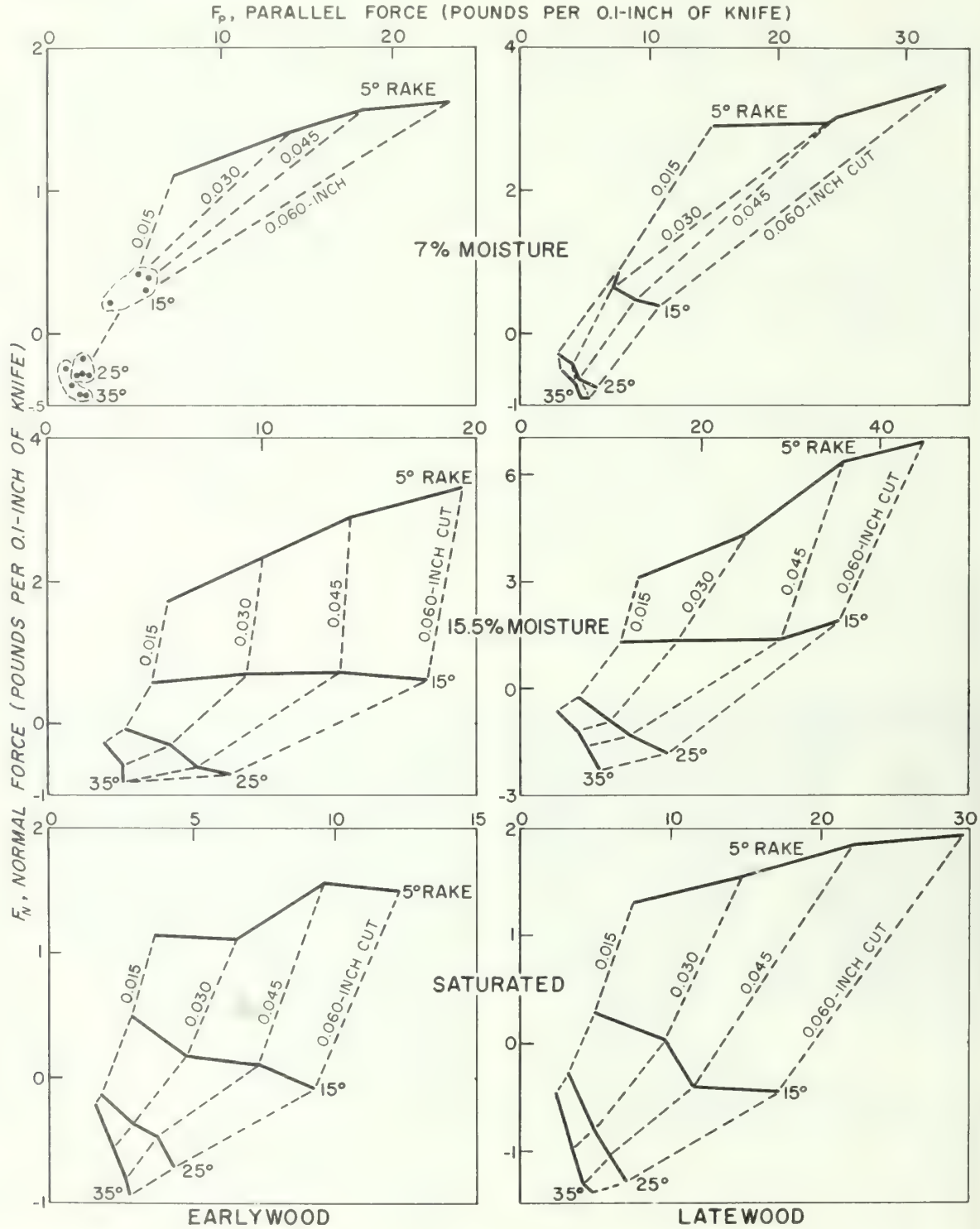


Figure 7.—*Effect of depth of cut, rake angle, and moisture content on average cutting forces for earlywood and latewood of southern pine; 90-0 cutting direction, orthogonal, 15° clearance angle, 2 inches per minute cutting velocity.*

Type II chips occur under certain conditions; continuous wood failures that extend from the cutting edge to the work surface ahead of the tool must be induced (fig. 8). The movement of the tool strains the wood ahead of the tool in compression parallel to the grain and causes diagonal shearing stresses; the wood fails and a continuous, smooth, spiral chip is formed. The radius of the spiral increases as chip thickness increases. Quite frequently latewood chips display laminae or layers. The resultant surface is excellent. In this study, thin chips, intermediate to high wood moisture contents, and rake angles of 5 to 15° favored formation of the Type II chip. In commercial practice Type II chips may be formed at rake angles somewhat higher than 15°—possibly up to 20°—because the splitting ahead of the knife may be less in the layered earlywood and latewood than in these homogeneous samples. The cutting edge is in intimate contact with the wood at all times, and dulling probably is rapid. Power demand is intermediate between that for Type I and Type III chips.

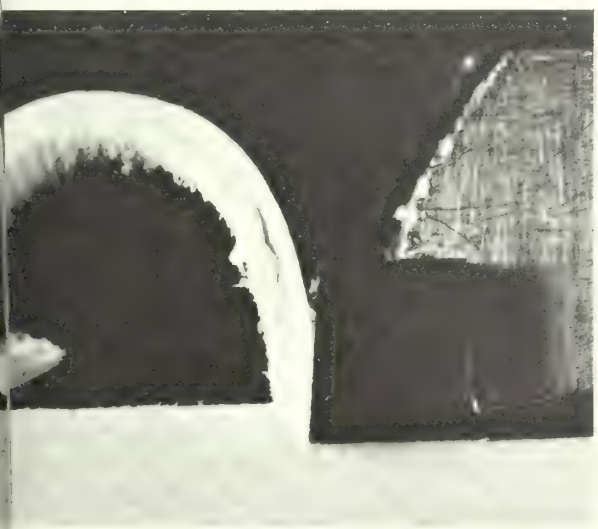


Figure 8.—*Franz Type II chip formed when making an 0.045-inch cut (90-0 direction) in loblolly pine latewood at 7-percent moisture content; 5° rake angle.*

Type III chips tend to form in cycles. Wood ahead of the tool is stressed in compression parallel to the grain. Rupture occurs in shear parallel to the grain and compression parallel to the grain, and is followed by compaction of the deformed wood against the tool face (fig. 9). Stresses are then transferred to unde-

Figure 9.—*Franz Type III chip formed when making an 0.045-inch cut (90-0 direction) in loblolly pine earlywood at 7-percent moisture content; 5° rake angle.*

formed areas that subsequently fail in turn. The chip does not escape freely up the tool face but remains interposed between face and area of continuing wood failure. When the accumulation of compressed material becomes critical, buckling takes place, the chip escapes upward, and the cycle begins again. Factors favorable to the formation of Type III chips include:

Small or negative rake angles

Dull cutting edges (the rounded edge presents a negative rake angle at tool-edge extremity)

High coefficient of friction between chip and tool face.

Wood failures ahead of the tool establish the surface. The failures frequently extend below the plane of the cut, and incompletely severed wood elements remain prominent on the surface. This machining defect is termed fuzzy grain. Power consumption is high and dulling is rapid.

Occurrence of the three chip types in orthogonal cutting of loblolly pine earlywood and latewood is summarized in table 2.

Effects of knife angles.—Rake angle exerted a strong effect on tool forces; forces were

Table 2.–*Typical chip types when orthogonally cutting loblolly pine wood parallel to the grain in the 90-0 direction*[1]

Moisture content and rake angle (degrees)	Chip type[2]			
	In earlywood		In latewood	
Saturated				
5	II	(III)	II	
15	II	(III)	I	(II)
25	I	(II)	I	
35	I		I	
15.5 percent				
5	III	(II)	II	(III)
15	II	(III)	II	
25	I	(II)	I	(II)
35	I		I	
7.0 percent				
5	III	(I)	II	(I)
15	I	(III)	I	
25	I		I	
35	I		I	

[1] Depths of cut ranged from 0.015 to 0.060 inch. Cutting velocity was 2 inches per minute, clearance angle 15°.

[2] The first number in each entry is major chip type as classified by Franz (1958); a second number in parentheses indicates that a combination of chip types was observed.

Table 3.–*Average tool forces per 0.1-inch of knife when orthogonally cutting loblolly pine parallel to the grain in the 90-0 direction*

Factor	Parallel force	Normal force[1]
	Pounds – –	
Cell type		
Earlywood	6.5	0.3
Latewood	12.5	.5
Moisture content, percent		
7	8.3	.4
15.5	12.9	.8
Saturated	7.3	.0
Depth of cut, inch		
0.015	5.2	.5
.030	8.3	.4
.045	10.8	.4
.060	13.7	.4
Rake angle, degrees[2]		
5	18.0	2.6
15	10.9	.5
25	5.4	–.6
35	3.7	–.7

[1] A negative normal force means that the knife tended to lift the workpiece; force was positive when the knife tended to push the workpiece away.

[2] Clearance angle constant at 15°.

negatively correlated with rake angle (fig. 10a and tables 3 through 7). Figure 7 shows the effect of rake angle at the three moisture contents studied.

The sharpness angle strongly affects the rate at which the cutting edge dulls. Minute fracturing of a freshly sharpened and honed knife edge occurs as the first few chips are cut and continues until equilibrium is reached between the cutting edge–which grows thicker and more rigid as the edge dulls–and the cutting forces; from this time wear proceeds at a slower rate. Effective rake angle is decreased as wear proceeds; cutting forces rise and chip formation is altered. In addition, the effective clearance angle is reduced and in fact may become negative; a negative clearance angle increases the cutting forces exerted by the knife and usually affects surface quality by causing raised grain–a roughened condition in which hard latewood is raised above the softer earlywood but not torn loose from it.

Effects of depth of cuts.–In orthogonal cutting, depth of cut is synonymous with thickness of the undeformed chip. As Lubkin (1957) and others have observed, in a given cutting situation two types of parallel-force curves may develop with changing chip thickness. When chips are very thin, the parallel force varies according to a power curve and F_i becomes zero at zero chip thickness.

$$F_p = Kt^m w \qquad (1)$$

where

F_p = parallel tool force
K = a constant
t = chip thickness
m = a constant between 1 and 0 (generally observed to be from 0.25 to 0.67)
w = width of chip

Beyond the region of very thin chips it is possible to approximate considerable portions of

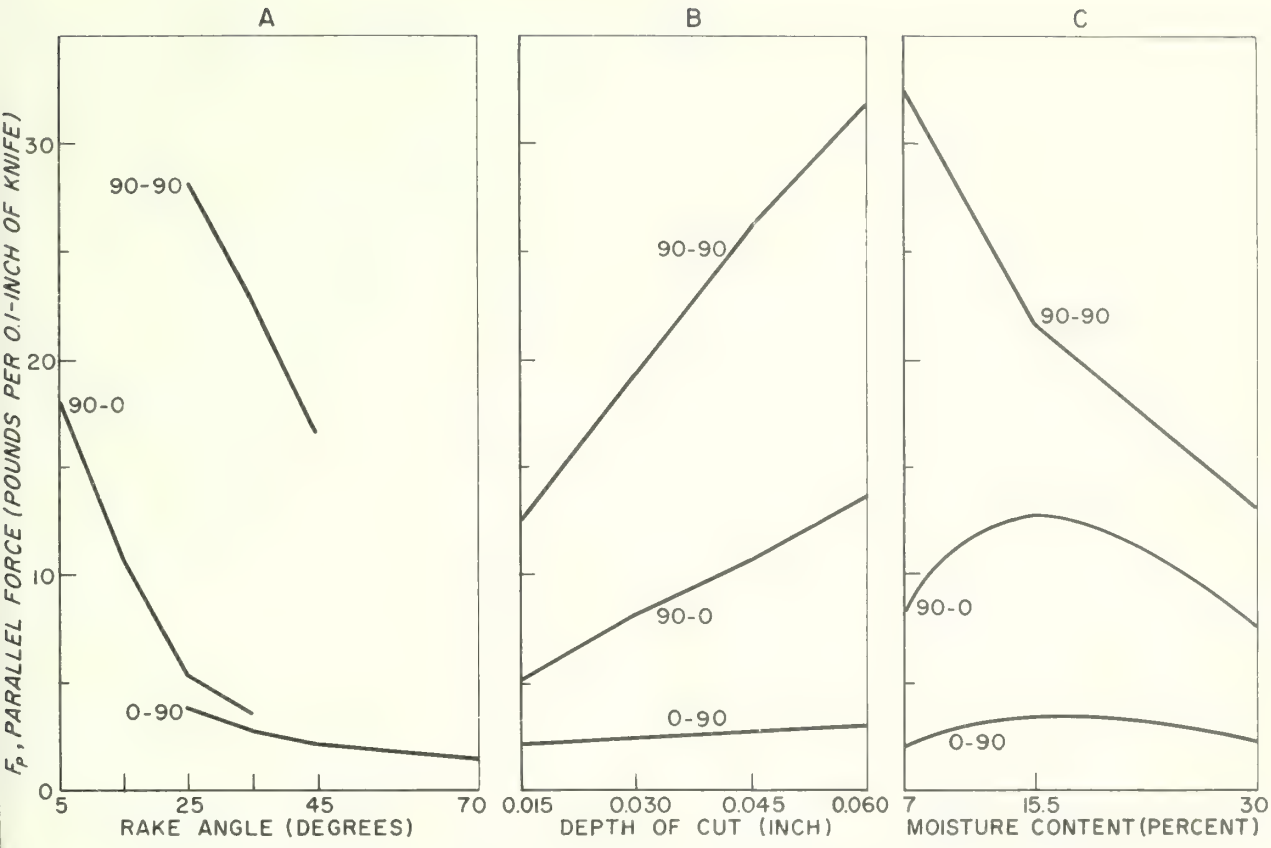


Figure 10.—*Effect of rake angle, depth of cut, and moisture content on average parallel cutting force. For these curves, data were pooled for both earlywood and latewood at a range of rake angles, three moisture contents (saturated, 15.5, and 7 percent), and four depths of cut (0.015, 0.030, 0.045, and 0.060 inch).*

his curve with a straight-line function of t that an be expressed:

$$F_p = (A+Bt)w \qquad (2)$$

constants A and B are suitably chosen.

In some situations the experimentally etermined parallel cutting force defined by quation 1 holds for the entire practical range of hip thicknesses. In other situations, the curve straightens beyond a certain chip thickness and ontinues linearly as described by equation 2.

If the data on parallel cutting force (tables 4 and 5) are averaged for both earlywood and latewood over all moisture contents and all rake angles, the resultant curves can be approximated by straight lines (fig. 10b). Figure 7 shows in more detail how cutting forces are related to chip thickness.

Effects of wood factors.—The specimens were cut on the radial face (fig. 1, 90-0 direction) and it was observed that most Type I chips failed in planes of weakness at ray locations. Had the specimens been machined on the tangential face, i.e., perpendicular to the rays, fewer Type I failures might have developed at the 25° rake angle.

Averaged over all rake angles, all depths of cut, and all moisture contents, latewood required much more cutting force per 0.1-inch width than earlywood:

Cell type	Specific gravity	F_p	F_n
		Pounds	
Latewood	0.85	12.5	0.5
Earlywood	.34	6.5	.3

Table 4. *Parallel tool forces per 0.1 inch of knife when orthogonally cutting loblolly pine latewood parallel to the grain in the 90-0 direction*[1,2]

Depth of cut and moisture content (percent)	Rake angle, degrees							
	5		15		25		35	
	Pounds							
0.015 inch								
7	14.4	(26.6)	7.6	(22.5)	3.0	(16.7)	3.3	(11.3)
15.5	13.0	(17.1)	11.1	(15.7)	6.3	(11.0)	4.0	(6.4)
Saturated	7.4	(11.1)	5.0	(7.8)	3.0	(5.3)	2.4	(3.7)
0.030 inch								
7	23.9	(49.2)	7.1	(39.9)	4.1	(22.3)	4.4	(15.7)
15.5	25.0	(32.7)	17.5	(28.7)	9.9	(16.9)	6.4	(10.3)
Saturated	14.8	(19.2)	9.6	(13.9)	5.0	(8.1)	3.5	(6.5)
0.045 inch								
7	24.4	(62.4)	8.8	(46.0)	4.5	(31.6)	4.8	(16.6)
15.5	36.1	(46.0)	28.8	(38.0)	11.8	(26.2)	7.1	(12.9)
Saturated	22.3	(28.0)	11.5	(19.5)	5.9	(10.7)	4.2	(7.8)
0.060 inch								
7	33.2	(87.3)	10.3	(52.6)	6.0	(31.0)	5.2	(21.6)
15.5	44.8	(57.6)	35.5	(51.8)	16.3	(34.9)	9.2	(15.3)
Saturated	29.6	(35.8)	17.3	(27.9)	7.1	(14.5)	4.7	(7.9)

[1] The first number in each entry is the average cutting force, the number following in parentheses is the average of the maximum forces observed in the five replications.

[2] Clearance angle 15°, cutting velocity 2 inches per minute.

Table 5.–*Parallel tool forces per 0.1 inch of knife when orthogonally cutting loblolly pine earlywood parallel to the grain in the 90-0 direction*[1,2]

Depth of cut and moisture content (percent)	Rake angle, degrees							
	5		15		25		35	
	Pounds							
0.015 inch								
7	7.3	(10.6)	5.8	(9.2)	2.0	(6.2)	1.3	(5.2)
15.5	5.5	(7.4)	4.9	(6.2)	3.7	(5.3)	2.5	(3.5)
Saturated	3.8	(5.2)	2.9	(4.0)	2.0	(3.0)	1.6	(2.4)
0.030 inch								
7	14.2	(18.8)	5.9	(16.5)	1.8	(9.8)	1.8	(7.3)
15.5	10.0	(12.6)	9.3	(11.1)	5.7	(8.4)	3.5	(5.8)
Saturated	6.6	(8.7)	5.0	(6.3)	2.9	(4.5)	2.2	(3.8)
0.045 inch								
7	18.5	(25.8)	3.7	(20.6)	2.0	(10.9)	2.2	(9.1)
15.5	14.0	(16.9)	13.6	(15.7)	6.9	(11.9)	3.6	(8.5)
Saturated	9.7	(11.9)	7.4	(9.5)	3.8	(5.7)	2.6	(4.3)
0.060 inch								
7	23.4	(33.9)	5.2	(25.7)	2.2	(13.4)	1.9	(10.9)
15.5	18.3	(22.7)	17.5	(20.2)	8.5	(14.5)	3.6	(10.7)
Saturated	12.4	(14.5)	9.3	(11.5)	4.3	(7.1)	2.9	(5.3)

[1] The first number in each entry is the average cutting force, the number following in parentheses is the average of the maximum forces observed in the five replications.

[2] Clearance angle 15°, cutting velocity 2 inches per minute.

Table 6.–*Normal tool forces per 0.1 inch of knife when orthogonally cutting loblolly pine latewood parallel to the grain in the 90-0 direction*[1,2,3]

Depth of cut and moisture content (percent)	Rake angle, degrees							
	5		15		25		35	
	Pounds							
0.015 inch								
7	2.8	(0.4 to 5.6)	0.8	(−0.3 to 2.5)	−0.3	(−1.8 to 0.5)	-0.5	(−2.5 to 0.4)
15.5	3.1	(1.6 to 4.5)	1.3	(−.4 to 2.6)	−.3	(−1.0 to .5)	.6	(−1.3 to .1)
Saturated	1.3	(.5 to 2.5)	.3	(−.4 to 1.1)	−.3	(−.8 to .4)	−.4	(−1.0 to .2)
0.030 inch								
7	2.9	(.4 to 6.1)	.7	(−1.1 to 2.7)	−.4	(−3.2 to .7)	−.7	(−3.9 to .4)
15.5	4.6	(2.6 to 7.7)	1.4	(−.2 to 3.0)	−.9	(−2.3 to .1)	−1.2	(−2.2 to −.2)
Saturated	1.6	(.6 to 2.9)	.0	(−1.0 to 1.1)	−.8	(−1.7 to .0)	−1.0	(−2.0 to .1)
0.045 inch								
7	3.0	(.6 to 7.7)	.4	(−1.8 to 2.5)	−.6	(−4.7 to .7)	.9	(−4.3 to .5)
15.5	6.7	(4.7 to 9.6)	1.4	(−.7 to 3.1)	−1.3	(−3.2 to .0)	−1.5	(−3.1 to −.3)
Saturated	1.8	(.8 to 3.4)	−.4	(−1.8 to .5)	−1.0	(−2.2 to .0)	−1.3	(−2.8 to .0)
0.060 inch								
7	3.4	(.5 to 9.1)	.4	(−2.0 to 2.3)	−.8	(−5.6 to .6)	-.9	(−5.9 to .4)
15.5	7.0	(3.8 to 11.1)	1.7	(−.7 to 4.1)	−1.8	(−4.4 to .0)	−2.4	(−4.1 to −.6)
Saturated	2.0	(.6 to 3.7)	−.4	(−1.7 to .7)	−1.3	(−3.2 to −.1)	−1.4	(−3.1 to −.1)

[1] The first number in each entry is the average cutting force; the numbers following in parentheses are minimum and maximum forces (average of five replications)

[2] Clearance angle 15°, cutting velocity 2 inches per minute

[3] A negative normal force means that the knife tended to lift the workpiece; force was positive when the knife tended to push the workpiece away

Table 7.–*Normal tool forces per 0.1 inch of knife when orthogonally cutting loblolly pine earlywood parallel to the grain in the 90-0 direction*[1,2,3]

Depth of cut and moisture content (percent)	Rake angle, degrees							
	5		15		25		35	
	Pounds							
0.015 inch								
7	1.1	(0.4 to 1.9)	0.3	(−0.1 to 0.9)	−0.2	(−0.9 to 0.4)	−0.2	(−1.3 to 0.2)
15.5	1.7	(.7 to 2.7)	.6	(.1 to 1.4)	.0	(−.4 to .3)	−.3	(−.7 to .0)
Saturated	1.2	(.5 to 2.1)	.5	(.1 to 1.0)	−.1	(−.4 to .3)	−.2	(−.5 to .2)
0.030 inch								
7	1.4	(.3 to 2.6)	.4	(−.6 to 1.1)	−.3	(−1.7 to .4)	−.3	(−2.3 to .2)
15.5	2.3	(1.1 to 4.1)	.7	(.3 to 1.3)	−.3	(−1.0 to .3)	−.6	(−1.5 to .0)
Saturated	1.1	(.7 to 2.2)	.2	(−.1 to .7)	−.4	(−.7 to .0)	−.6	(−1.1 to −.1)
0.045 inch								
7	1.6	(.4 to 3.0)	.2	(−1.2 to 1.2)	−.3	(−2.2 to .4)	−.4	(−3.1 to .2)
15.5	2.9	(1.8 to 4.6)	.6	(.1 to 1.3)	−.6	(−1.7 to .2)	−.8	(−2.3 to .1)
Saturated	1.6	(1.0 to 2.9)	.1	(−.3 to .6)	−.5	(−1.0 to .1)	−.8	(−1.5 to −.2)
0.060 inch								
7	1.6	(.4 to 3.5)	.4	(−1.6 to 1.4)	−.3	(−2.9 to .3)	−.4	(−3.6 to .3)
15.5	3.3	(1.8 to 5.1)	.6	(.0 to 1.5)	−.7	(−2.4 to .2)	−.8	(−2.9 to .2)
Saturated	1.5	(.9 to 2.2)	−.1	(−.5 to .7)	−.7	(−1.5 to .1)	−.9	(−2.0 to .1)

[1] The first number in each entry is the average cutting force; the numbers following in parentheses are minimum and maximum forces (average of five replications)

[2] Clearance angle 15°, cutting velocity 2 inches per minute

[3] A negative normal force means that the knife tended to lift the workpiece; force was positive when the knife tended to push the workpiece away

Maximum parallel cutting force per 0.1-inch of width was inversely proportional to moisture content when averaged over all rake angles, all depths of cut, and both cell types:

Moisture content (percent)	F_p
	Lbs.
7	24.6
15.5	18.8
Saturated	10.5

Average parallel cutting force was positively correlated with moisture content when cutting in the 90-0 direction at the lower moisture contents (fig. 10c, tables 4 and 5). When dry wood is cut, the forming chip fails as a cantilever beam and there are intervals when no force is required; hence the average is low even though the maximum force is high.

To summarize the effects of the principal factors in 90-0 cutting, earlywood and latewood data were pooled and multiple regression equations were developed to relate depth of cut (inch), rake angle (degrees), moisture content (decimal fraction of ovendry weight), and specific gravity (ovendry volume and weight) to average parallel (F_p) and normal (F_n) cutting forces (pounds) per 0.1-inch width of specimen.

$$F_p = 6.996 + 2{,}178.193\left[\frac{(\text{specific gravity})(\text{depth of cut})}{\sqrt{\text{rake angle}}}\right] - 274.182\,(\text{specific gravity})(\text{depth of cut}) - 409.777\,(\text{moisture content})^2 + 147.362\,(\text{moisture content}) \quad (3)$$

Within the stated limits of the factors, equation 3 accounted for 75 percent of the variation with a standard error of the estimate of 4.7 pounds.

$$F_n = -0.659 - 6.610\,(\text{moisture content})^2 + 4.751\left[\frac{1}{\sqrt{\text{rake angle}}}\right] - 87.518\,(\text{specific gravity})(\text{depth of cut}) + 336.975\left[\frac{(\text{specific gravity})(\text{depth of cut})}{\sqrt{\text{rake angle}}}\right] \quad (4)$$

Equation 4 accounted for 71 percent of the variation with a standard error of the estimate of 0.93 pound.

PERPENDICULAR TO GRAIN: 0-90 DIRECTION

In commercial practice, veneer is cut in the 0-90 direction from heated logs with a knife having a rake angle of approximately 70° and a clearance angle of close to 0°. The knife is used in conjunction with a nosebar to compress the wood ahead of the cutting edge. The compression reduces the severity of checks in the forming veneer. This paper reports on orthogonal cutting of room-temperature wood without a nosebar and at a variety of rake angles.

Chip formation.—For 0-90 cutting, McMillin (1958) has accounted for the formation of various chip types in terms of the mechanical properties of the wood; the explanation will not be duplicated here.

As defined by Leney (1960), continuous veneer is formed in an unbroken sheet in which the original wood structure is essentially unchanged by the cutting process. With a suitably sharp knife, and a thin cut, this can be accomplished so that the veneer has relatively unbroken surfaces on both sides (fig. 11).

Following initial incision, the cells above the cutting edge move upward along the face of the knife. They are restrained by the wood above them and therefore are compressed. As the compression increases, a force normal to the knife face is developed, together with a frictional force along the face of the knife. As the cut proceeds, the forces reach a maximum when the veneer begins to rotate or bend as a cantilever beam. This bending creates a zone of maximum tension above the cutting edge and causes compression on the top or face of the forming veneer.

As depth of cut is increased, rake angle decreased, or cutting edge dulled, critical zones of stress develop, as depicted in figure 12. In Zone 1 maximum tension due to bending develops close to the cutting edge and at right angles to the long axis of the zone as drawn; failure occurs as a tension check. In Zone 2 the frictional force along the face of the knife may create a more or less horizontal shear plane between the compressed cells at the knife-chip interface and the resisting wood above them. In Zone 3 the cutting edge deflects the wood elements into a slight bulge preceding the edge, and the somewhat compacted cell walls may eventually fail in tension either above or below the cutting plane (compression tearing).

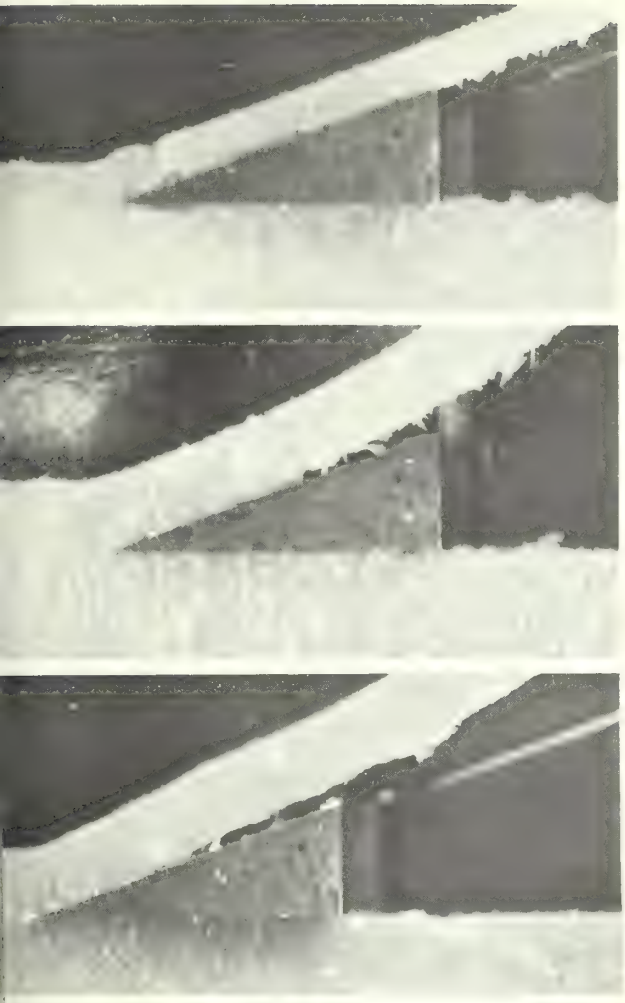


Figure 11.—*Continuous veneer cut from saturated loblolly pine in 0-90 direction; 70° rake angle and 20° sharpness angle (zero clearance angle).*

A. *Earlywood, 0.030-inch cut.*
B. *Earlywood, 0.060-inch cut.*
C. *Latewood, 0.060-inch cut.*

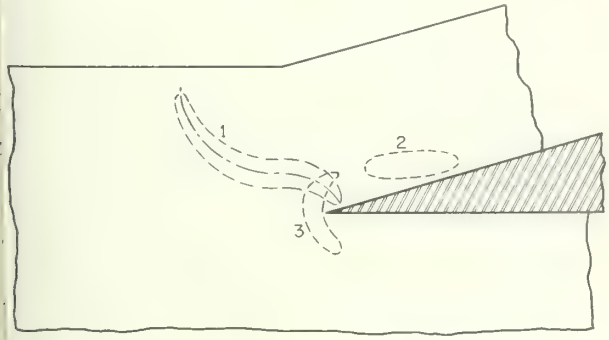


Figure 12.—*Critical zones of stress in veneer cutting without a nosebar: (1) tension, (2) shear, (3) compression tearing.*

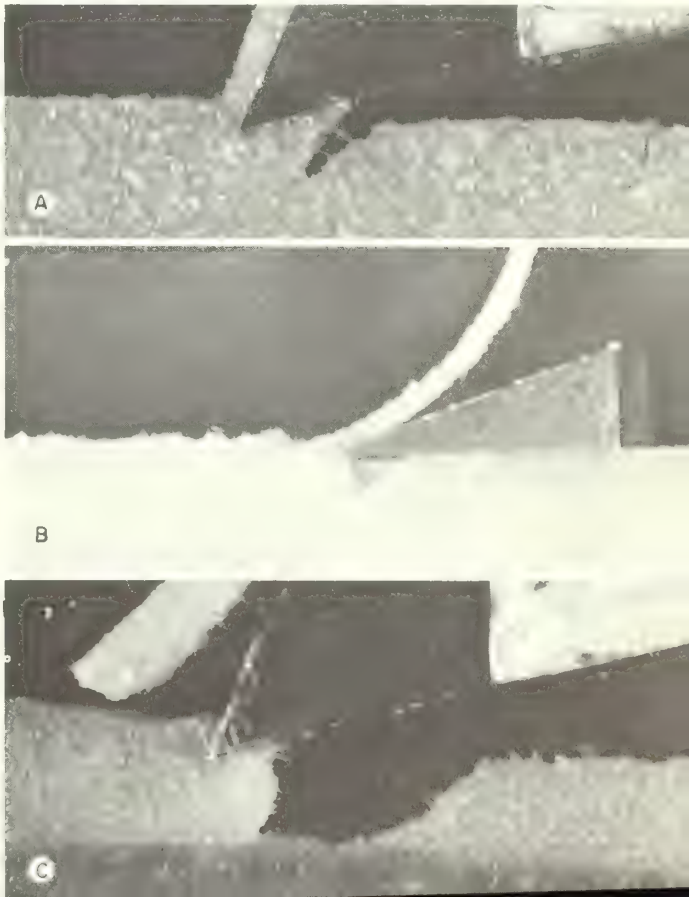
In this study compression tearing was prominent in earlywood when rake angles were between 25 and 70°. The degree of tearing ranged from moderate (fig. 13a) to severe (fig. 13c); in the latter case, the earlywood was simply pushed off the underlying latewood.

With rake angles of 45° and lower, latewood failed as a cantilever beam at all moisture contents (fig. 14). The knife with 70° rake and 0° clearance cut continuous veneer from saturated latewood with only an occasional failure as a cantilever beam (fig. 11c). With all knives (rake angles 25, 35, 45, and 70°) both earlywood and latewood developed deep tension checks when cut at 7-percent moisture content (figs. 14,15).

The knife with 70° rake cut the best veneer; saturated wood yielded the highest proportion of continuous veneer, although there was some compression tearing in earlywood. Generally, tension checks occurred when veneer was cut from wood dried to a mositure content of 15.5 or 7 percent. In studying figures 11, 13, 14, 15,

Figure 13.—*Compression tearing in veneer cut in the 0-90 direction from saturated loblolly pine earlywood.*

A. *Rake angle 25°, depth of cut 0.030 inch.*
B. *Rake angle 70°, depth of cut 0.015 inch.*
C. *Rake angle 25°, depth of cut 0.045 inch.*



it should be remembered that the specimens were very narrow and that chip formation in wide specimens of mixed earlywood and latewood might develop somewhat differently.

Cutting forces.—Cutting forces were strongly affected by cell type, moisture content, depth of cut, and rake angle (table 8).

Figure 14.—*Veneer fails as a cantilever beam when cut in 0-90 direction from loblolly pine latewood at 7-percent moisture content with a rake angle of 45° and clearance angle of 15°. Veneer is 0.030-inch thick in top photo and 0.045 in bottom.*

Figure 15.—*Tension checks in 0.060-inch veneer cut in 0-90 direction from loblolly pine earlywood at 7 percent moisture content. Rake angle 70°. Sharpness angle 20°.*

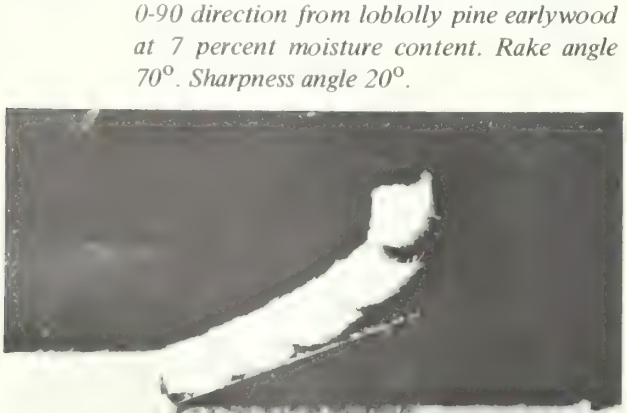


Table 8.—*Average tool forces per 0.1 inch of knife when orthogonally cutting loblolly pine veneer in the 0-90 direction*

Factor	Parallel force	Normal force [1]
	— — *Pounds* — —	
Cell type		
Earlywood	2.6	0.1
Latewood	2.7	−.8
Moisture content, percent		
7	2.2	−.5
15.5	3.5	−.4
Saturated	2.2	−.2
Depth of cut, inch		
0.015	2.2	−.1
.030	2.5	−.3
.045	2.7	−.4
.060	3.0	−.6
Rake angle, degrees [2]		
25	3.9	.1
35	2.8	−.3
45	2.2	−.6
70	1.6	−.6

[1] A negative normal force means that the knife tended to lift the workpiece; force was positive when the knife tended to push the workpiece away.

[2] Clearance angle 15°, except that knife with 70° rake had zero clearance.

Moisture content was negatively correlated with maximum parallel cutting force per 0.1-inch of width (but not with maximum normal force) when averaged over all rake angles, all depths of cut, and both cell types.

Moisture content (percent)	F_p
	Lbs.
7	9.8
15.5	8.2
Saturated	4.7

Average parallel cutting force, however was relatively independent of moisture conten when data on all rake angles, all depths of cut and both cell types were pooled (fig. 10c, 0-90) Figure 16 and tables 9 and 10 give a mor detailed view of the interactions with moistur content. When veneer is cut from dry wood, th forming chip fails as a cantilever beam and ther are intervals when no force is required; henc the average is low. In wet wood, howeve continuous veneer is formed and the averag parallel force is high.

Table 9.–*Parallel tool forces per 0.1 inch of knife when orthogonally cutting loblolly pine latewood veneer in the 0-90 direction*[1,2]

Depth of cut and moisture content (percent)	Rake angle, degrees							
	25		35		45		70	
	Pounds							
0.015 inch								
7	2.9	(14.7)	2.0	(12.3)	2.1	(8.8)	2.0	(4.3)
15.5	4.3	(8.7)	4.0	(6.6)	2.9	(4.7)	2.3	(3.7)
Saturated	2.3	(4.5)	2.1	(3.6)	1.7	(2.8)	1.4	(1.9)
0.030 inch								
7	3.0	(20.7)	2.5	(15.2)	1.8	(11.4)	2.0	(5.0)
15.5	5.9	(14.8)	3.9	(10.0)	2.3	(7.2)	2.4	(5.0)
Saturated	2.6	(6.9)	2.3	(6.1)	1.6	(4.1)	1.5	(2.5)
0.045 inch								
7	3.1	(25.6)	1.9	(16.1)	2.2	(15.9)	1.7	(5.3)
15.5	5.5	(17.7)	3.9	(14.8)	2.5	(9.2)	2.3	(5.6)
Saturated	3.5	(10.0)	2.2	(7.8)	1.5	(5.9)	1.6	(2.9)
0.060 inch								
7	2.6	(26.9)	1.7	(18.2)	2.8	(17.9)	1.5	(5.3)
15.5	6.6	(21.5)	4.0	(16.3)	3.3	(11.7)	2.9	(7.1)
Saturated	3.7	(12.7)	2.7	(10.3)	1.7	(6.8)	1.7	(3.7)

[1] The first number in each entry is the average cutting force; the number following in parentheses is the average of the maximum forces observed in the five replications.

[2] Clearance angle 15°, except that knife with 70° rake had zero clearance. Cutting velocity 2 inches per minute.

Table 10.–*Parallel tool forces per 0.1 inch of knife when orthogonally cutting loblolly pine earlywood veneer in the 0-90 direction*[1,2]

Depth of cut and moisture content (percent)	Rake angle, degrees							
	25		35		45		70	
	Pounds							
0.015 inch								
7	2.6	(5.5)	2.0	(4.8)	1.7	(4.1)	1.0	(1.8)
15.5	3.3	(5.1)	2.8	(4.1)	1.8	(3.7)	1.0	(1.9)
Saturated	2.2	(2.9)	1.8	(2.6)	1.5	(2.2)	1.3	(1.9)
0.030 inch								
7	3.4	(8.2)	1.9	(6.3)	1.9	(5.6)	1.1	(2.2)
15.5	4.7	(6.8)	3.6	(6.7)	2.5	(5.6)	1.4	(2.8)
Saturated	3.0	(4.5)	2.2	(3.5)	1.9	(3.2)	1.2	(1.9)
0.045 inch								
7	3.5	(10.1)	2.4	(7.5)	1.8	(6.0)	1.1	(2.2)
15.5	6.7	(10.1)	4.9	(8.8)	2.5	(6.1)	1.6	(3.0)
Saturated	3.6	(5.4)	2.6	(4.7)	2.1	(3.8)	1.2	(1.9)
0.060 inch								
7	3.4	(9.6)	2.3	(8.1)	2.0	(5.6)	1.1	(2.4)
15.5	7.6	(13.0)	5.1	(10.2)	3.0	(7.0)	1.4	(2.6)
Saturated	4.0	(6.0)	3.3	(5.5)	2.8	(4.7)	1.3	(2.0)

[1] The first number in each entry is the average cutting force; the number following in parentheses is the average of the maximum forces observed in the five replications.

[2] Clearance angle 15°, except that knife with 70° rake had zero clearance. Cutting velocity 2 inches per minute.

Parallel cutting force was negatively correlated with rake angle. With the rake angles evaluated, the average normal force was always negative in latewood. With earlywood, however, the 25 and 35° rake angles generally caused a positive normal force, i.e., the tool pushed on the workpiece (fig. 16 and tables 11 and 12).

Depth of cut had a relatively small effect on the average parallel cutting force; figure 10b (0-90) shows data averaged over all rake angles, all moisture contents, and both cell types. Figure 16 and tables 9 through 12 show the interactions for both normal and parallel forces.

To summarize the effects of the major factors in 0-90 veneer cutting, earlywood and latewood data were pooled and multiple regression equations were developed to relate depth of cut (inch), rake angle (degrees), moisture content (expressed as a decimal fraction), and specific gravity (ovendry volume and weight) to average parallel and normal cutting forces (pounds) per 0.1-inch width of specimen.

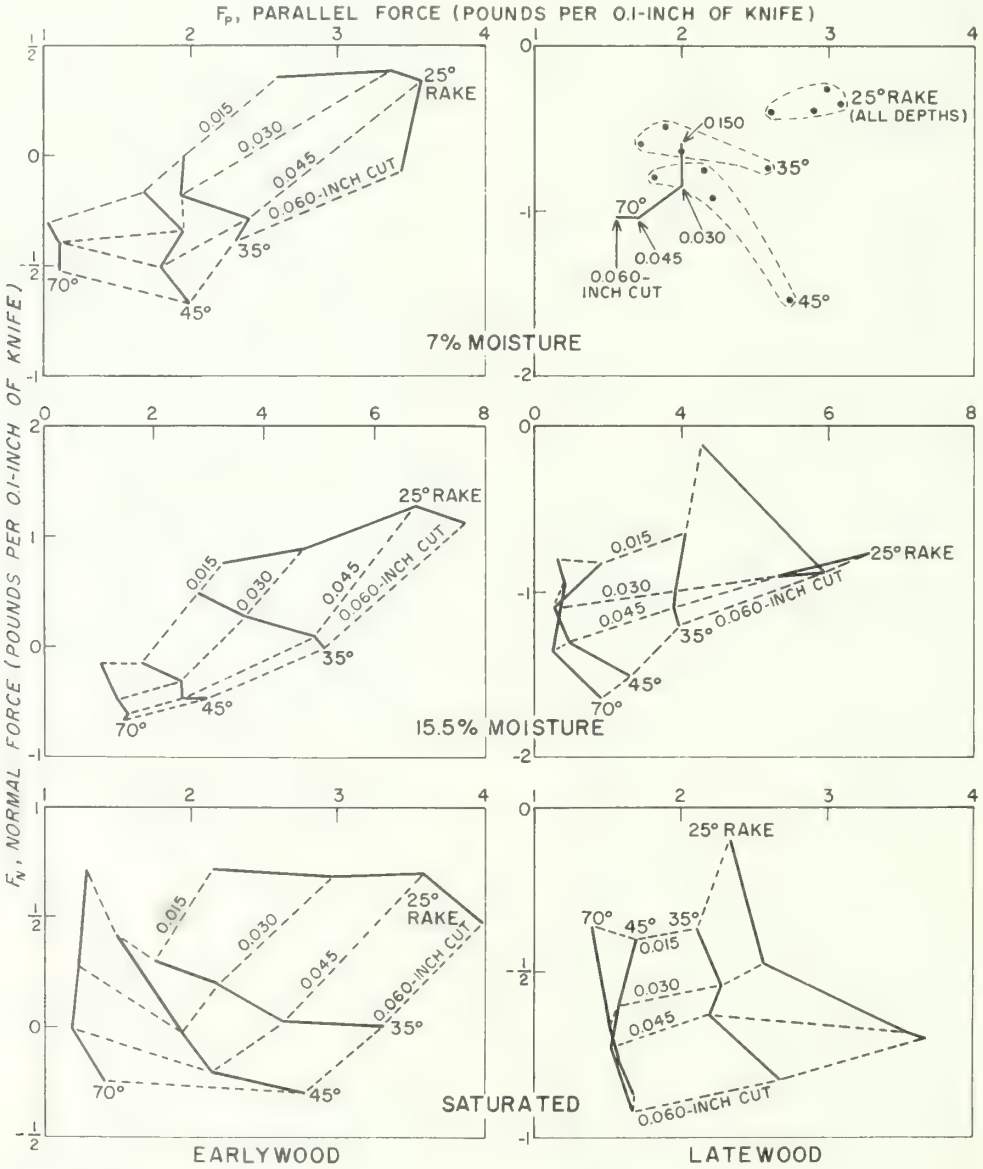


Figure 16.—*Effect of depth of cut, rake angle, and moisture content on average cutting forces for earlywood and latewood of southern pine; 0-90 cutting direction, orthogonal, 15° clearance angle, 2 inches per minute cutting velocity.*

Table 11.—*Normal tool forces per 0.1 inch of knife when orthogonally cutting loblolly pine latewood veneer in the 0-90 direction*[1,2,3]

Depth of cut and moisture content (percent)	Rake angle, degrees							
	25		35		45		70	
	Pounds							
0.015 inch								
7	−0.4	(−2.3 to 1.3)	−0.7	(−3.5 to 0.5)	−0.7	(−3.5 to 0.6)	−0.6	(−1.6 to 0.5)
15.5	−.1	(−1.4 to .6)	−.6	(−1.8 to .4)	−.8	(−1.9 to .0)	−.8	(−1.6 to .1)
Saturated	−.1	(−.6 to .4)	−.3	(−1.1 to .3)	−.4	(−1.2 to .4)	−.4	(−.8 to .2)
0.030 inch								
7	−.3	(−4.0 to 1.5)	−.7	(−5.0 to .3)	−.8	(−5.8 to .5)	−.9	(−2.3 to .4)
15.5	−.9	(−3.0 to .8)	−1.0	(−3.1 to .5)	−1.1	(−3.6 to .3)	−.9	(−2.2 to .0)
Saturated	−.5	(−1.5 to .5)	−.5	(−2.2 to .4)	−.6	(−2.2 to .5)	−.7	(−1.5 to .3)
0.045 inch								
7	−.3	(−4.7 to 1.2)	.5	(−5.4 to .2)	.9	(−7.0 to .5)	−1.0	(−2.9 to .4)
15.5	−.9	(−3.9 to 1.1)	−1.1	(−5.4 to .3)	−1.3	(−5.5 to .1)	−1.3	(−2.8 to .0)
Saturated	−.7	(−2.3 to .6)	−.6	(−2.9 to .3)	−.7	(−3.4 to .6)	−.8	(−2.0 to .4)
0.060 inch								
7	−.4	(−4.7 to .5)	−.6	(−7.4 to .8)	−1.6	(−9.5 to .6)	−1.0	(−3.4 to .5)
15.5	−.8	(−4.7 to 1.7)	−1.2	(−5.8 to .7)	−1.5	(−6.4 to .2)	−1.6	(−3.3 to .2)
Saturated	−.7	(−3.0 to .5)	−.8	(−4.1 to .3)	−.9	(−3.9 to .4)	−.9	(−2.9 to .6)

[1] The first number in each entry is the average cutting force, the numbers following in parentheses are minimum and maximum forces (average of five replications)
[2] Clearance angle 15°, except that knife with 70° rake had zero clearance. Cutting velocity 2 inches per minute
[3] A negative normal force means that the knife tended to lift the wood; force was positive when the knife tended to push the workpiece away

Table 12.—*Normal tool forces per 0.1 inch of knife when orthogonally cutting loblolly pine earlywood veneer in the 0-90 direction*[1,2,3]

Depth of cut and moisture content (percent)	Rake angle, degrees							
	25		35		45		70	
	Pounds							
0.015 inch								
7	0.4	(−0.5 to 2.4)	0.0	(−0.5 to 1.3)	−0.2	(−0.9 to 0.6)	−0.3	(−0.7 to 0.2)
15.5	.8	(−.2 to 2.1)	.5	(−.3 to 1.3)	−.1	(−.7 to 1.0)	−.1	(−.5 to .3)
Saturated	.7	(.2 to 1.4)	.3	(−.1 to .9)	−.4	(.0 to 1.1)	−.7	(.2 to 1.2)
0.030 inch								
7	.4	(−.7 to 2.7)	−.2	(−1.0 to 1.4)	−.3	(−1.3 to .8)	−.4	(−1.2 to .2)
15.5	.9	(−.4 to 2.5)	.3	(−.9 to 1.9)	−.3	(−1.3 to .6)	−.5	(−1.0 to .1)
Saturated	.7	(−.1 to 1.9)	.2	(−.3 to 1.0)	−.1	(−.4 to .8)	−.3	(−.1 to .7)
0.045 inch								
7	.3	(−1.1 to 2.5)	−.3	(−1.4 to 1.0)	−.5	(−2.1 to .6)	−.4	(−1.6 to .4)
15.5	1.3	(−.5 to 3.6)	.1	(−1.4 to 2.6)	−.5	(−1.6 to .3)	−.6	(−1.3 to .2)
Saturated	.7	(.0 to 1.8)	.0	(−.7 to .9)	−.2	(−.7 to .5)	.0	(−.4 to .6)
0.060 inch								
7	−.1	(−1.4 to 1.9)	−.4	(−2.0 to .9)	−.7	(−2.6 to .7)	−.5	(−1.8 to .5)
15.5	1.1	(−1.0 to 4.3)	.0	(−1.9 to 2.3)	−.4	(−2.0 to .7)	−.6	(−1.4 to .1)
Saturated	.5	(−.4 to 1.7)	.0	(−.7 to .8)	−.3	(−.8 to .6)	−.2	(−.6 to .3)

[1] The first number in each entry is the average cutting force, the numbers following in parentheses are minimum and maximum forces (average of five replications)
[2] Clearance angle 15°, except that knife with 70° rake had zero clearance. Cutting velocity 2 inches per minute
[3] A negative normal force means that the knife tended to lift the wood; force was positive when the knife tended to push the workpiece away

$$F_p = 5.902 + 63.565\left(\frac{1}{\text{rake angle}}\right) + 747.561\left(\frac{\text{depth of cut}}{\text{rake angle}}\right) - 0.0338\left(\frac{1}{\text{moisture content}^2}\right) + 3.318\left(\frac{1}{\sqrt{\text{moisture content}}}\right) \quad (5)$$

Equation 5 accounts for 64 percent of the variation with a standard error of the estimate of 0.85 pound.

$$F_n = -2.241 - 3.572\left(\sqrt{\text{depth of cut}}\right) + 694.063\left(\frac{1}{\text{rake angle}^2}\right) + 1.296\left(\frac{1}{\sqrt{\text{specific gravity}}}\right) + 0.0305\,(\text{moisture content})(\text{rake angle}) \quad (6)$$

Equation 6 accounts for 69 percent of the variation with a standard error of the estimate of 0.36 pound.

Tool forces when cutting in the 0-90 direction are influenced by the strength of wood in tension perpendicular to the grain, shear perpendicular to the grain, and compression perpendicular to the grain. Because wood is relatively weak when so stressed, tool forces are substantially less in this mode than in the 90-0 or 90-90 directions.

PERPENDICULAR TO GRAIN: 90-90 DIRECTION

McKenzie (1961) recognized two chip types when cutting a variety of softwoods and hardwoods perpendicular to the grain. The same general types were observed in this study of loblolly pine. Average cutting forces are relatively constant during formation of Type I chips. Below the cutting plane, splits occur parallel to the grain. The splits may be minute and virtually invisible, in which case the surface is quite good (fig. 17a), or they may be fairly frequent and deep, in which case the surface is poor (fig. 17c). Each subchip above the cutting plane is formed by shear along the grain.

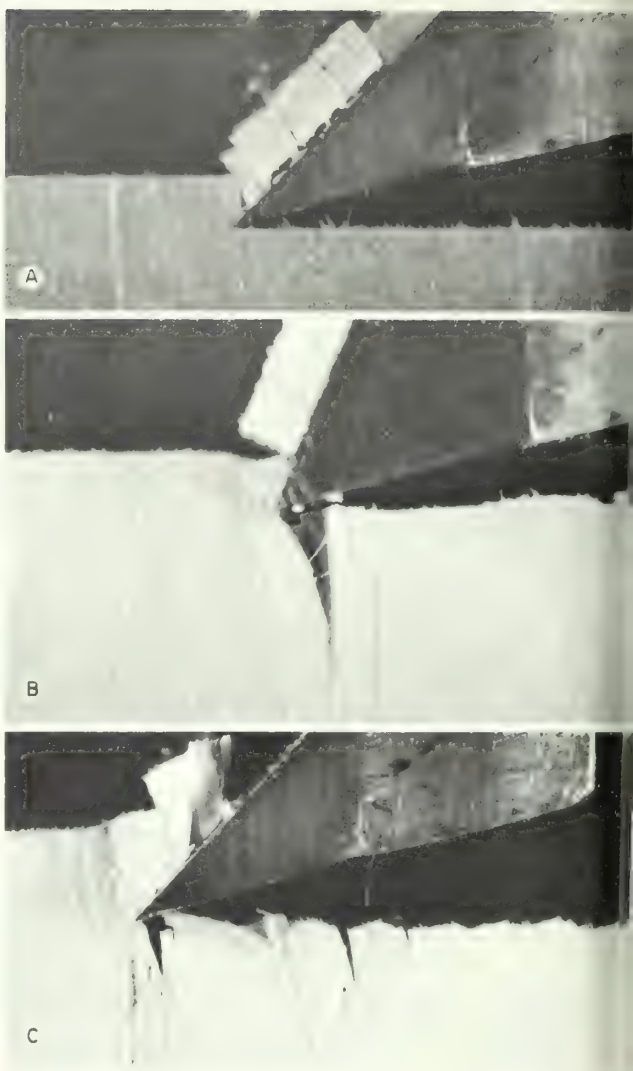


Figure 17.—*McKenzie Type I chips formed when orthogonally cutting 0.060-inch deep across the grain of loblolly pine in the 90-90 direction.*
A. *Latewood, saturated, rake angle 45°.*
B. *Earlywood, saturated, rake angle 25°.*
C. *Latewood at 7-percent moisture content, rake angle 45°.*

Cyclic variation of average cutting forces with successive cuts is usual when Type II chips are formed. Failures occur perpendicular to the grain and at a variable distance below the cutting plane (fig. 18). After the initial cut, therefore, the knife edge may not be engaged in all portions of its path. The mechanics of these two chip formations are explained in McKenzie (1961) or Koch (1964, pp. 93-109).

Type I chips and good surfaces can be achieved by cutting the wood at relatively high

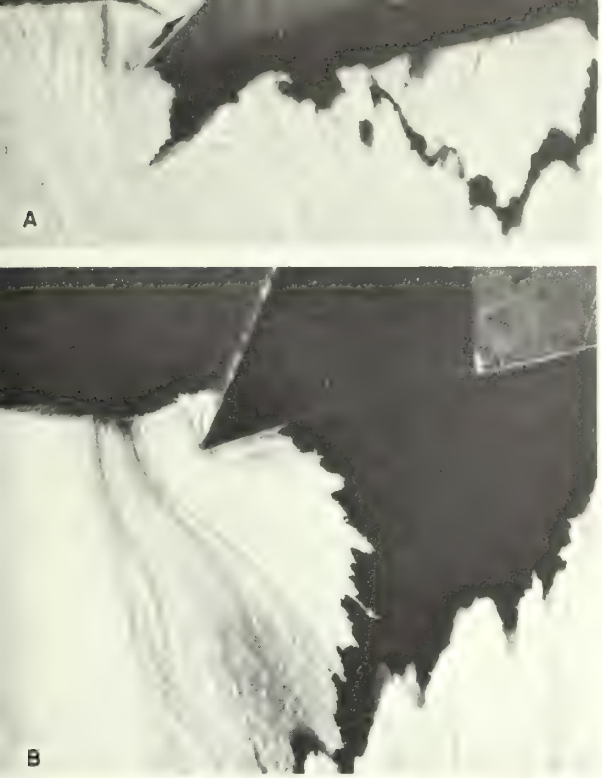


Figure 18.–*McKenzie Type II chips formed when orthogonally cutting loblolly pine earlywood of 7-percent moisture content across the grain in the 90-90 direction.*
A. *Rake angle 45°, 0.060-inch cut.*
B. *Rake angle 25°, 0.045-inch cut.*

moisture content with a very sharp knife having a high rake angle, e.g., 45° (fig. 17a). Although supporting data are not at hand, it is probable that high cutting velocities, e.g., 10,000 feet per minute, are conducive to formation of Type I chips. Figure 19 suggests the idea that a high-velocity cutter might be resisted by the inertia of the fibers, and therefore could accomplish clean severance and a Type I chip. It is more difficult to cut a Type I chip in earlywood than in latewood, particularly in wood of low moisture content. Type II chips are most frequent in wood of low moisture content (table 13).

Cutting forces.–Cutting forces were strongly affected by cell type, moisture content, depth of cut, and rake angle (table 14).

When averaged over all rake angles, all depths of cut, and both cell types, maximum cutting forces per 0.1 inch of specimen width were negatively correlated with wood moisture content.

Table 13.–*Typical chip types when orthogonally cutting loblolly pine across the grain in the 90-90 direction*[1]

Moisture content and rake angle (degrees)	Chip type[2]	
	In earlywood	In latewood
Saturated		
25	I	I
35	I	I
45	I	I
15.5 percent		
25	II (I)	I
35	II	I
45	II (I)	I
7 percent		
25	II	II (I)
35	II	II (I)
45	II	II (I)

[1]Depths of cut ranged from 0.015 to 0.060 inch. Cutting velocity was 2 inches per minute, clearance angle 15°.
[2]The first number in each entry is major chip type as classified by McKenzie (1961); a second number in parentheses indicates that a combination of chip types was observed.

Table 14.–*Average tool forces per 0.1 inch of knife when orthogonally cutting loblolly pine across the grain in the 90-90 direction*

Factor	Parallel force	Normal force[1]
	– – – *Pounds* – – –	
Cell type		
Earlywood	11.4	2.4
Latewood	33.6	–8.8
Moisture content, percent		
7	32.5	–2.1
15.5	21.9	–3.6
Saturated	13.1	–3.9
Depth of cut, inch		
0.015	12.4	–1.3
.030	19.5	–2.5
.045	26.2	–3.7
.060	31.9	–5.3
Rake angle, degrees[2]		
25	28.2	–.7
35	22.8	–3.6
45	16.6	–5.4

[1]A negative normal force means that the knife tended to lift the workpiece; force was positive when the knife tended to push the workpiece away.
[2]All knives had a 15° clearance angle; cutting velocity 2 inches per minute.

Moisture content (percent)	F_p	F_n
	Lbs.	*Lbs.*
7	43.3	6.8
15.5	29.0	1.6
Saturated	16.6	−1.7

Average cutting forces displayed a similar negative correlation. Figure 20 and tables 15 through 18 give a detailed view of interactions with moisture content. From figure 20 it is seen that the normal force was positive only in dry earlywood.

Rake angle was negatively correlated with parallel (tables 15 and 16) and normal tool forces (tables 14, 17, 18).

Depth of cut had a positive linear correlation with parallel cutting force when data for earlywood and latewood were pooled over all moisture contents and rake angles (fig. 10b). Figure 20 illustrates an interaction; normal force was unaffected by depth of cut only when dry earlywood was cut with a knife having a 45° rake angle.

To summarize the effects of the major factors in 90-90 cutting, earlywood and latewood data were pooled and a multiple regression

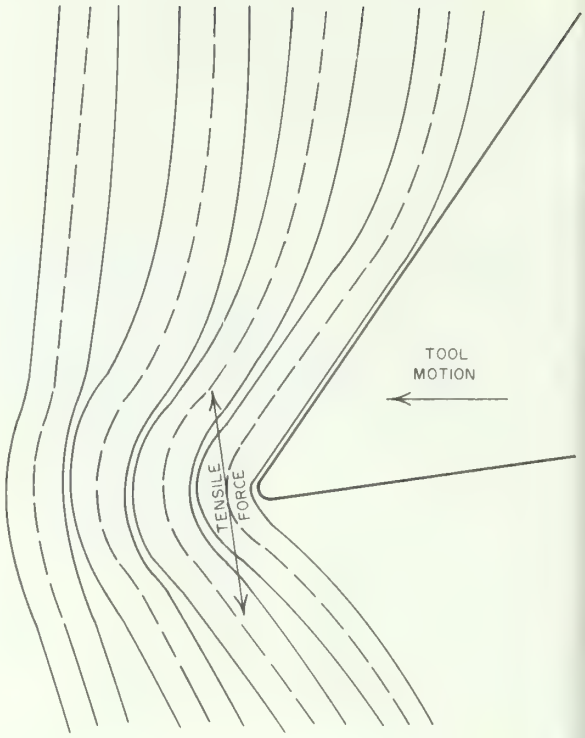


Figure 19.—*In the 90-90 mode, failure at the cutting edge is due to tension across the cutting plane.*

Table 15.—*Parallel tool forces per 0.1 inch of knife when orthogonally cutting loblolly pine latewood across the grain in the 90-90 direction*[1,2]

Depth of cut and moisture content (percent)	Rake angle, degrees					
	25		35		45	
	Pounds					
0.015 inch						
7	32.4	(42.8)	29.1	(39.6)	21.7	(31.7)
15.5	22.8	(27.7)	18.2	(22.9)	13.5	(17.7)
Saturated	11.8	(14.8)	11.7	(14.3)	6.2	(7.8)
0.030 inch						
7	56.6	(73.5)	42.1	(62.3)	33.6	(51.8)
15.5	37.9	(45.5)	24.5	(32.2)	17.6	(24.7)
Saturated	20.2	(24.4)	20.4	(24.9)	10.0	(13.5)
0.045 inch						
7	71.9	(81.7)	52.2	(80.5)	46.1	(66.7)
15.5	53.7	(66.0)	33.8	(43.7)	24.3	(34.2)
Saturated	26.3	(31.8)	27.3	(32.4)	14.0	(18.9)
0.060 inch						
7	85.9	(119.7)	65.7	(99.7)	59.1	(87.1)
15.5	68.0	(80.5)	38.4	(53.4)	28.1	(40.7)
Saturated	31.8	(37.4)	35.6	(42.0)	17.5	(24.1)

[1] The first number in each entry is the average cutting force, the number following in parentheses is the average of the maximum forces observed in the five replications.

[2] Clearance angle 15°, cutting velocity 2 inches per minute.

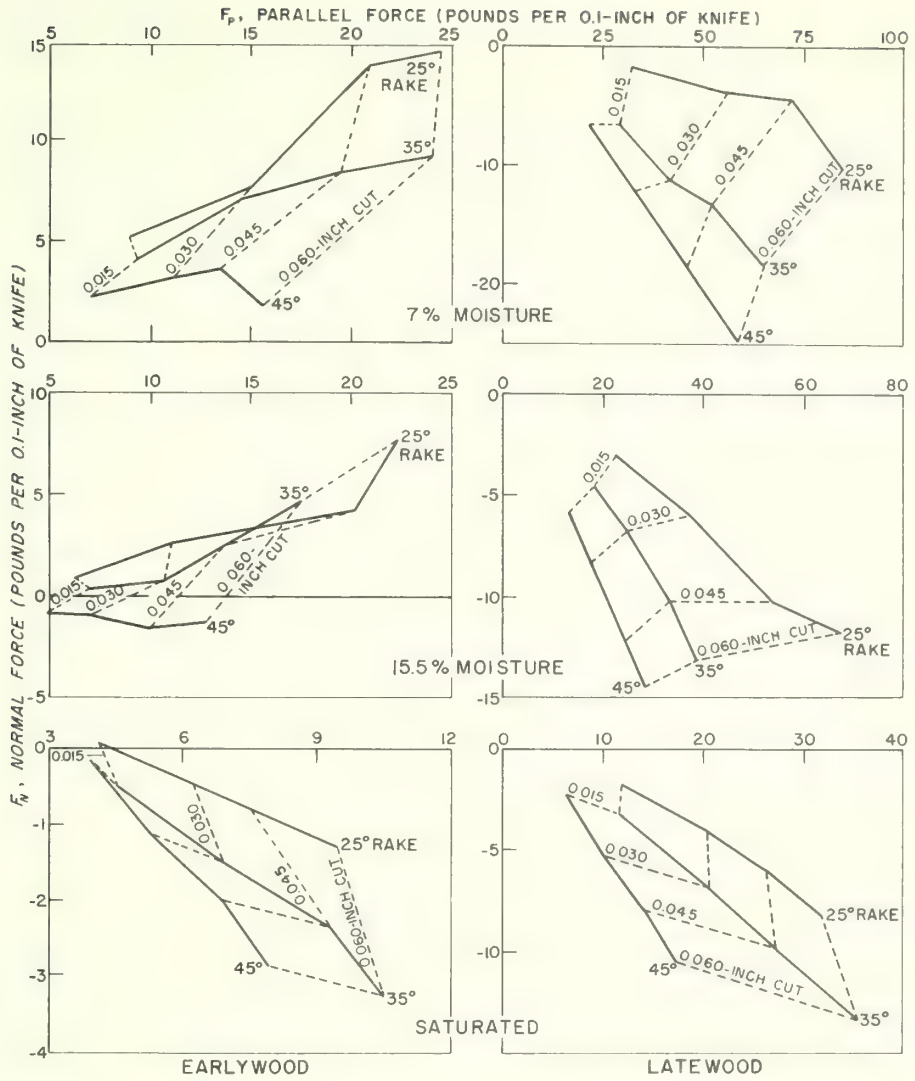


Figure 20.—*Effect of depth of cut, rake angle, and moisture content on average cutting forces for earlywood and latewood of southern pine; 90-90 cutting direction, orthogonal, 15° clearance angle, 2 inches per minute cutting velocity.*

nalysis was made to relate depth of cut (inch), ake angle (degrees), moisture content (ex- ressed as a decimal fraction), and specific ravity (ovendry volume and weight) to average arallel and normal cutting forces per 0.1-inch idth of specimen.

$$P = + 1.964 + 561.346\left(\frac{\text{specific gravity}}{\text{rake angle}}\right) + 2{,}650.962\left[\frac{(\text{specific gravity})(\text{depth of cut})}{(\text{rake angle})(\text{moisture content})}\right] \quad (7)$$

quation 7 accounts for 87 percent of the ariation with a standard error of the estimate of .8 pounds.

$$F_n = - 0.285 - 180.253\,(\text{specific gravity})(\text{depth of cut}) + 6.699\left(\frac{\text{depth of cut}}{\text{moisture content}}\right) - 50.615\left[\frac{(\text{specific gravity})(\text{depth of cut})}{\text{moisture content}}\right] + 894.843\left[\frac{\text{depth of cut}}{(\text{moisture content})(\text{rake angle})}\right] \quad (8)$$

Equation 8 accounts for 82 percent of the variation with a standard error of the estimate of 3.4 pounds.

Table 16.–*Parallel tool force per 0.1 inch of knife when orthogonally cutting loblolly pine earlywood across the grain in the 90-90 direction* [1,2]

Depth of cut and moisure content (percent)	Rake angle, degrees					
	25		35		45	
	Pounds					
0.015 inch						
7	8.9	(11.0)	9.3	(11.9)	7.1	(10.2)
15.5	6.2	(9.7)	7.0	(9.2)	4.9	(7.4)
Saturated	4.1	(5.5)	4.5	(5.5)	4.0	(4.9)
0.030 inch						
7	15.0	(19.5)	14.0	(19.5)	11.0	(14.8)
15.5	11.2	(15.8)	10.8	(14.9)	7.1	(10.6)
Saturated	6.1	(8.2)	6.9	(9.3)	5.3	(6.6)
0.045 inch						
7	21.8	(27.5)	19.6	(27.3)	13.4	(18.6)
15.5	20.3	(25.2)	13.9	(18.8)	9.9	(14.6)
Saturated	7.6	(10.6)	9.3	(13.4)	6.8	(9.2)
0.060 inch						
7	24.4	(34.1)	24.0	(32.5)	15.5	(24.8)
15.5	22.4	(31.4)	17.6	(26.9)	12.8	(22.8)
Saturated	9.5	(13.0)	10.6	(15.4)	7.8	(10.8)

[1] The first number in each entry is the average cutting force, the number following in parentheses is the average of the maximum forces observed in the five replications

[2] Clearance angle 15°, cutting velocity 2 inches per minute

Table 17.–*Normal tool forces per 0.1 inch of knife when orthogonally cutting loblolly pine latewood across the grain in the 90-90 direction* [1,2]

Depth of cut and moisture content (percent)	Rake angle, degrees					
	25		35		45	
	Pounds					
0.015 inch						
7	−1.7	(−6.6 to 3.8)	−6.7	(−12.0 to −1.6)	−6.7	(−12.3 to −1.3)
15.5	−3.1	(−4.9 to −.9)	−4.5	(−6.4 to −1.4)	−5.7	(−8.1 to −2.6)
Saturated	−1.6	(−2.7 to −.5)	−3.1	(−4.2 to −1.4)	−2.3	(−3.6 to −1.0)
0.030 inch						
7	−3.7	(−11.6 to 4.3)	−11.2	(−19.4 to −2.4)	−12.0	(−20.6 to −2.2)
15.5	−6.0	(−8.6 to −2.9)	−6.7	(−10.3 to −2.5)	−8.4	(−12.2 to −3.0)
Saturated	−3.9	(−5.6 to −2.1)	−6.7	(−8.7 to −3.7)	−5.1	(−7.9 to −2.0)
0.045 inch						
7	−4.4	(−15.5 to 8.7)	−13.2	(−27.8 to −2.2)	−18.4	(−31.1 to −2.5)
15.5	−10.1	(−13.7 to −4.7)	−10.2	(−14.4 to −3.6)	−12.1	(−16.6 to −3.7)
Saturated	−5.7	(−7.9 to −3.2)	−9.8	(−12.5 to −4.5)	−7.9	(−11.1 to −3.1)
0.060 inch						
7	−10.4	(−24.4 to 1.9)	−18.4	(−35.9 to −4.2)	−25.0	(−40.6 to −4.4)
15.5	−11.7	(−16.1 to −4.5)	−13.0	(−18.7 to −4.4)	−14.5	(−21.9 to −4.7)
Saturated	−8.1	(−10.1 to −4.4)	−13.4	(−16.7 to −7.5)	−10.5	(−14.8 to −3.6)

[1] The first number in each entry is the average cutting force, the numbers following in parentheses are minimum and maximum forces (average of five replications)

[2] Clearance angle 15°, cutting velocity 2 inches per minute

Table 18.–*Normal tool forces per 0.1 inch of knife when orthogonally cutting loblolly pine earlywood across the grain in the 90-90 direction*[1,2]

Depth of cut and moisture content (percent)	Rake angle, degrees					
	25		35		45	
	Pounds					
0.015 inch						
7	5.3	(1.5 to 8.9)	4.1	(0.4 to 7.7)	2.2	(−1.0 to 6.3)
15.5	.8	(−.8 to 2.4)	.4	(−1.3 to 2.3)	−.9	(−2.1 to .4)
Saturated	.0	(−.4 to .6)	−.5	(−1.1 to .1)	−.1	(−.6 to .3)
0.030 inch						
7	8.8	(1.9 to 16.2)	7.4	(.5 to 14.9)	3.0	(−1.6 to 8.4)
15.5	2.7	(−1.0 to 6.5)	.7	(−3.0 to 4.8)	−.9	(−3.9 to 2.6)
Saturated	−.5	(−1.3 to .3)	−1.5	(−2.6 to −.5)	−1.1	(−1.8 to −.3)
0.045 inch						
7	13.2	(2.7 to 20.7)	8.7	(.3 to 17.1)	3.8	(−2.4 to 10.0)
15.5	4.2	(−2.7 to 10.9)	2.5	(−2.8 to 8.7)	−1.5	(−5.8 to 4.2)
Saturated	−.8	(−1.9 to .2)	−2.4	(−4.2 to .9)	−2.0	(−3.5 to −.6)
0.060 inch						
7	14.6	(2.8 to 28.7)	9.5	(−.2 to 18.7)	1.9	(−4.5 to 8.6)
15.5	7.7	(−1.2 to 18.1)	−4.7	(−3.2 to 13.1)	−1.4	(−6.9 to 4.5)
Saturated	−1.4	(−2.7 to .0)	−3.2	(−5.2 to −1.3)	−2.8	(−4.7 to −1.1)

[1] The first number in each entry is the average cutting force, the numbers following in parentheses are minimum and maximum forces (average of five replications)
[2] Clearance angle 15°, cutting velocity 2 inches per minute

FORCE COMPARISON FOR THREE CUTTING DIRECTIONS

Because chip formation when cutting in the 90-90 direction requires wood to be failed in tension parallel to the grain (fig. 19), parallel cutting forces are much higher than in the 0-90 and 90-0 directions. While the data in table 19 are restricted to a rake angle of 35° and one depth of cut, the trends shown are valid for cuts from 0.015 to 0.060 inch deep and also for a rake angle of 25°.

The data on maximum and minimum cutting forces reveal some figures of interest to machine designers.

In the 90-0 (planing) direction, forces were greatest (per 0.1-inch of knife) for 0.060-inch cuts in latewood:

F_p was maximum at 87.3 pounds when cutting with 5° rake angle in wood at 7-percent moisture content

F_n was maximum at 11.1 pounds when cutting with 5° rake angle in wood at 15.5-percent moisture content

F_n was minimum at −5.9 pounds when cutting with 35° rake angle in wood at 7-percent moisture content.

In the 0-90 (veneer) direction, forces were greatest (per 0.1-inch of knife) when cutting 0.060-inch deep:

F_p was maximum at 26.9 pounds when cutting with 25° rake angle in latewood at 7-percent moisture content

F_n was maximum at 4.3 pounds when cutting with 25° rake angle in earlywood at 15.5-percent moisture content

F_n was minimum at −9.5 pounds when cutting with 45° rake angle in latewood at 7-percent moisture content.

In the 90-90 (crosscut) direction, forces (per 0.1-inch of knife) were greatest when cutting 0.060-inch chips at 7-percent moisture content:

F_p was maximum at 119.7 pounds when cutting with 25° rake angle in latewood

F_n was maximum at 28.7 pounds when cutting with 25° rake angle in earlywood

F_n was minimum at −40.6 pounds when cutting with 45° rake angle in latewood.

Table 19.—*Average parallel tool force per 0.1 inch of knife where orthogonally cutting loblolly pine in the three major directions with a rake angle of 35°; depth of cut 0.030 inch*[1]

Moisture content (percent)	Cell type	0-90	90-0	90-90
		Pounds		
7	Earlywood	1.9	1.8	14.0
	Latewood	2.5	4.4	42.1
15.5	Earlywood	3.6	3.5	10.8
	Latewood	3.9	6.4	24.5
Saturated	Earlywood	2.2	2.2	6.9
	Latewood	2.3	3.5	20.4

[1] Clearance angle 15°, cutting velocity 2 inches per minute

LITERATURE CITED

Cade, J. C., and Choong, E. T.
1969. Influence of cutting velocity and log diameter on tensile strength of veneer across the grain. Forest Prod. J. 19(7): 52-53.

Franz, N. C.
1958. An analysis of the wood-cutting process. Ph.D. Thesis. Univ. Mich., Ann Arbor. 152 pp.

Koch, P.
1955. An analysis of the lumber planing process: Part I. Forest Prod. J. 5: 255-264.

Koch, P.
1956. An analysis of the lumber planing process: Part II. Forest Prod. J. 6: 393-402.

Koch, P.
1964. Wood machining processes. 530 pp. N.Y.: Ronald Press Co.

Koch, P.
1968. Wood machining abstracts, 1966 and 1967. USDA Forest Serv. Res. Pap. SO-34, 38 pp. South. Forest Exp. Sta., New Orleans, La.

Koch, P., and McMillin C. W.
1966a. Wood machining review, 1963 through 1965. Part I. Forest Prod. J. 16(9): 76-82, 107-115.

Koch, P., and McMillin, C. W.
1966b. Wood machining review, 1963 through 1965. Part II. Forest Prod. J. 16(10): 43-48.

Leney, L.
1960. Mechanism of veneer formation at the cellular level. Mo. Agr. Exp. Sta. Res. Bull. 744, 111 pp.

Lubkin, J. L.
1957. A status report on research in the circular sawing of wood. Vol. 1. Cent. Res. Lab. Tech. Rep. CRL-T-12, 216 pp. Amer. Mach. & Foundry Co., Greenwich, Conn.

Lutz, J. F.
1964. How growth rate affects propertie of softwood veneer. Forest Prod. J. 14: 97-102.

Lutz, J. F.
1967. Research at Forest Products Laboratory reveals that heating southern pine bolts improves veneer quality. Plywood and Panel Mag. 7(9 20-28.

Lutz, J. F., Duncan, C. G., and Scheffer, T. C.
1966. Some effects of bacterial action on rotary-cut southern pine veneer. Forest Prod. J. 16(8): 23-28.

Lutz, J. F., Haskell, H. H., and McAlister, R.
1962. Slicewood . . . a promising new wood product. Forest Prod. J. 12: 218-227.

Lutz, J. F., Mergen, A., and Panzer, H.
1967. Effect of moisture content and speed of cut on quality of rotary-cut veneer. USDA Forest Serv. Res. Note FPL-0176, 13 pp. Forest Prod. Lab., Madison, Wis.

Lutz, J. F., Mergen, A., and Panzer, H. R.
1969. Control of veneer thickness during rotary cutting. Forest Prod. J. 19(12): 21-28.

Lutz, J. F., and Patzer, R. A.
1966. Effects of horizontal roller-bar openings on quality of rotary-cut southern pine and yellow-poplar veneer. Forest Prod. J. 16(10): 15-25.

McKenzie, W. M.
1961. Fundamental aspects of the wood cutting process. Ph.D. Thesis. Univ. Mich., Ann Arbor. 161 pp.

McMillin, C. W.
1958. The relation of mechanical properties of wood and nosebar pressure in the production of veneer. Forest Prod. J. 8: 23-32.

Peters, C. C., Mergen, A. F., and Panzer, H. R.
1969. Effect of cutting speed during thick slicing of wood. Forest Prod. J. 19(11): 37-42.

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Morphology and Length Correlated in Terminal Flushes of Longleaf Pine Saplings

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Southern Forest Experiment Station
Forest Service
U.S. Department of Agriculture

1970

Morphology and Length Correlated in Terminal Flushes of Longleaf Pine Saplings

R. M. Allen[1] and N. M. Scarbrough[2]

In longleaf pine (Pinus palustris *Mill.*) *saplings growing in southern Mississippi the length of the first or spring flush was significantly correlated with that of the second flush; the correlation of length between flushes two and three was also statistically significant. The correlations were due more to similarities in internode elongation than to node number.*

Flush length was closely correlated with number of nodes and with internode elongation in the second and third flushes. Probably because a severe spring drought in 1963 reduced the growth of only those trees with the greatest growth potential, length of the first flush of that year was correlated with number of nodes but not with internode elongation.

During periods of reasonably good growing conditions in the field, variation in node number accounted for almost three times more variation in flush length than did internode elongation. Over a range of annual environments, variation in number of nodes accounted for 47 percent of the variation in length of the spring flush and 74 percent of that of summer flushes.

No influence of one flush upon another was detected among the flushes of growth within a growing season. There was, however, a negative correlation between summer growth and spring growth in the following year.

A thorough understanding of the elongation process could lead to improved methods for increasing height growth of southern pines. This paper is the second in a series that describes detailed studies of terminal shoot elongation. Reported here are correlations between some morphological characteristics of terminal flushes and the length they attain in longleaf pine saplings.

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A brief review of things already known about longleaf pine explains th approach taken in the studies described here. In pines, dwarf shoot pr mordia are formed in the axils of cataphylls or scales. The needles ar initiated from the apical meristems of the short shoots.

In some respects, the pattern of terminal bud development in longlea pine appears to follow that described by Sacher (5) for *P. lambertian* Dougl. Initiation of dwarf shoot primordia for *P. lambertiana* begins i mid-May in Berkeley, California, and continues through most of the sum mer. Internodal elongation takes place in the winter bud in the followin spring and essentially all of the activity is below the shoot apical meristen The shoot apical meristem remains relatively inactive until sometime in th grand period of elongation, when it starts forming the next bud. Accordin to Sacher (5), the winter bud is essentially a telescoped shoot which co tains all of the nodes[3] of next spring's flush of growth.

Winter buds in longleaf pine probably do not start to form until som time in late summer. In a study in southern Mississippi (*1*), the bud b came readily distinguishable in August. It began elongating in late Januar but there was no visible activity in the bud tip until about 40 days late Rapid elongation of the second flush began about 30 days after the activit in the bud tip was noted and before the winter bud had elongated to 5 percent of its final length. This activity, as in *P. lambertiana,* took pla during the grand period of growth in the spring flush rather than after e tension growth had ceased as in *P. ponderosa* Laws. (*5*) and *P. resino* Ait. (*4*).

The number of nodes in a given flush of longleaf pine is probab predetermined in the bud, and none are laid down after the bud star to elongate. The growth of the shoot, then, is essentially a two-sta process, the formation of a bud and its subsequent elongation. A study individual shoots of number of nodes, the product of bud formation, ar length, the result of bud formation and elongation, should give some i sight into the architecture of shoot growth. Therefore, some of the rel tionships between length of flush and number of dwarf shoots, i.e., ferti nodes, were examined.

Methods and Results

Measurements were made in the fall of 1963 on the first three flush of 1963 growth of longleaf saplings in a 5-year-old plantation on an o field. The numbers of dwarf shoots and lengths of the shoots bearing the were determined for the spring flush on 93 saplings and for the seco

3 In the present discussion, the term "node" refers to the point of attachment of a cataph the space between two succeeding nodes is the internode. Node does not refer to a branch whorl.

nd third flushes of 61 of the saplings. n addition, length of the sterile cataphyll one, diameter of the shoot at the mid- oint of each flush, and average length f needles at the midpoint of each flush ere recorded for 38 of the saplings.

Another measurement involved the phyl- otaxy of the flushes. If the nodes are con- ected by imaginary lines, a number of elixes, or parastichies, may be projected pon the shoot (fig. 1) (2). The distance etween the five parastichous intercepts earest the midpoint of each flush was easured to estimate internode elongation see arrows in fig. 1).

Similar measurements were made on the rst flush of 1964 growth on 57 saplings om the same plantation.

Data were also obtained from 40 domi- ant longleaf pine saplings growing in a earby plantation. These trees, which av- raged about 20 feet tall, were cut in the ll of 1964, the length of each flush was easured, and dwarf shoots in each flush ounted for the year 1961 through 1964.

The correlations between some growth mponents and total growth were de- rmined both within and between the ushes.

The average length of the zone of sterile ataphylls was practically the same in all ree flushes. This similarity is of doubt- l importance because the length of the erile zone of the spring flush relative to e length of the sterile zone in the third ush varied greatly among trees. The ngth of the sterile cataphyll zone was not

Figure 1. *Stem of longleaf pine sapling showing some of the parastichies that can be projected from the helical arrangement of the nodes.*

examined in detail as were other characteristics of shoots.

The spring flush was about three times the length of the second or third flush. Approximately the same difference was found in the number of nodes. Internode elongation (the distance between five parastichous intercepts) was about 21 percent greater in the spring flush than in either the second or third flush.

The spring flush had the largest diameter of the three flushes at time of measurements, but it also was the oldest. There was no difference in average needle length among the three flushes.

Mean values for the various measurements are given in table 1.

Table 1. – *Mean values of some characteristics of three consecutive flushes of longleaf pine saplings*

Flush	Length of zone of sterile cataphylls	Length of zone of dwarf shoots	Dwarf shoots	Internode elongation[1]	Stem diameter	Needle length
	Cm.	*Cm.*	*No.*	*Cm.*	*Mm.*	*Cm.*
First	2.8	47.4	415	10.0	29.0	39.8
Second	3.0	18.3	172	8.4	25.3	39.8
Third	3.0	15.1	150	8.2	22.1	38.0

1 Distance between five parastichous intercepts.

Correlation With Length

For 1963 data, correlations were computed between lengths of flushes and various attributes of the shoot within the flush for the first three flushes of growth in the 38 trees:

Comparison	First flush	Second flush	Third flush
Length with number of nodes	0.73*	0.76*	0.88*
Length with stem diameter	.10	.06	.12
Length with internode elongation	.14	.56*	.56*
Length with needle length	.17	– .10	.02

Length was not correlated with stem diameter in any of the flushes. Apparently those factors which are important in determining shoot length

* Denotes statistical significance at the 5-percent level of confidence–the level used throughout this paper.

are not important in determining initial shoot diameter. Shoot length was not correlated with needle length.

In the second and third flushes, length was positively correlated with number of nodes and estimated internode elongation. Evidently, in these two flushes the factors operating within the tree and in the environment to control the number of nodes that were formed similarly influenced internode elongation.

Spring flush length was correlated with number of nodes, but not internode elongation. To further explore the possible relation between number of nodes and flush length, the data were grouped and the two variables were plotted against each other in figure 2. While length was indeed correlated with number of nodes in the spring flush, the relationship was curvilinear. Length increased at a decreasing rate with increases in the number of nodes.

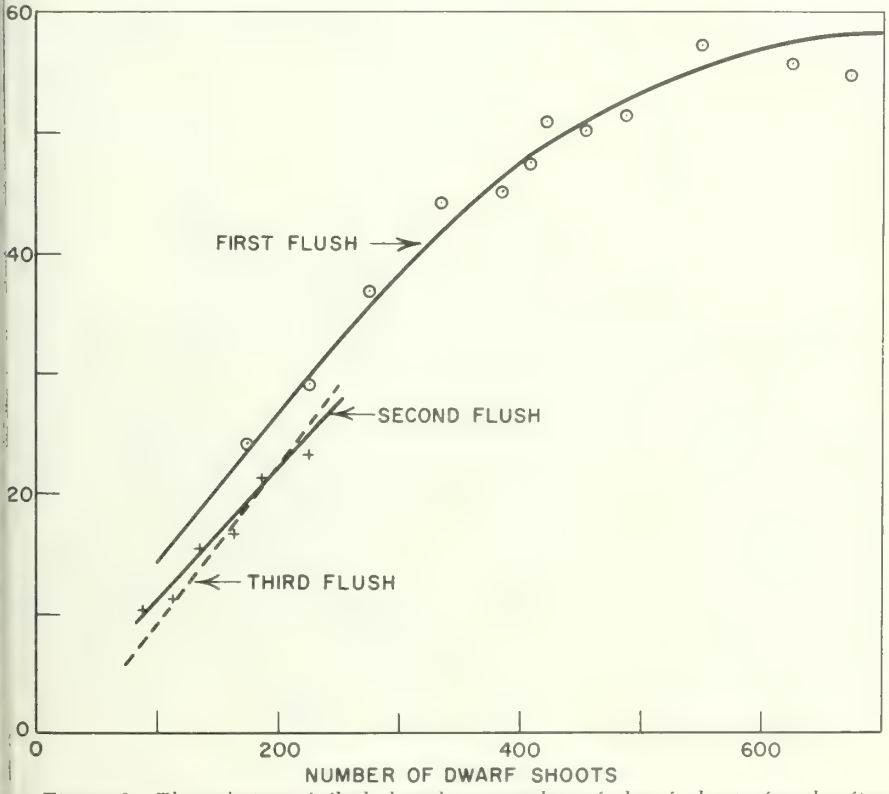

Figure 2. *The relation of flush length to number of dwarf shoots for the first three flushes of growth of longleaf saplings in 1963.*

To clarify growth relationships in the spring flush, internode elongation was plotted over number of nodes. The curve was constructed graphically with data from the spring flush of the 38 saplings (fig. 3). The linear coefficient of determination for the data of figure 3 was zero, but 74 percent of the variation in internode elongation was accounted for by the variation in node number with the curve.

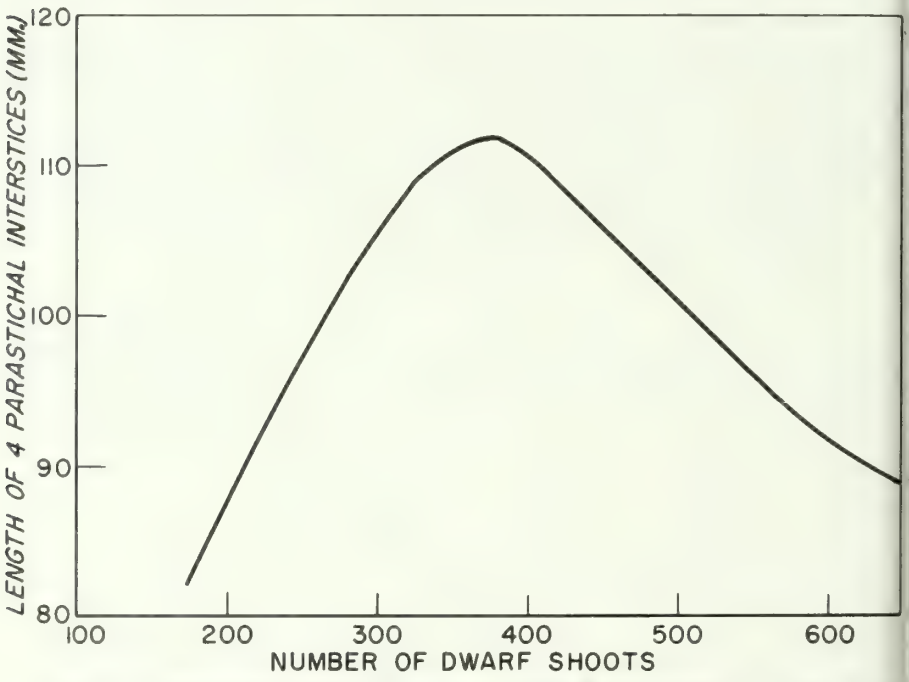

Figure 3. *Relationship between length of internode and number of dwarf shoots in the spring flush of longleaf saplings.*

The effect of number of nodes on internodal elongation explained the curvilinearity in figure 2. Up to about 400 nodes, the increase in length of the spring flush was largely linear, but with further increases in number of nodes, the rate of increase in flush length declined due to the decreasing amount of internode elongation. The second or third flushes of these trees did not have over 400 nodes, and total length increased in about the same manner as in spring flushes with less than 400 nodes. These relationships between number of nodes and internode elongation also account for the lack of correlation between length and internode elongation in the spring flush when such correlation was found in the second and third flushes.

A biological explanation can be proposed for the curvilinear response of internode length with number of nodes. The very dry April 1963 (table

2) could have affected those saplings with many nodes more than those with fewer nodes—especially if saplings with relatively few nodes had a different pattern of elongation than those with many nodes. These possibilities were investigated.

Table 2.—*Monthly rainfall at Harrison Experimental Forest, Saucier, Mississippi*

Month	Year				1946-63 average
	1961	1962	1963	1964	
			Inches		
January	5.63	6.06	4.79	8.16	4.52
February	9.52	5.10	5.02	4.41	4.46
March	10.80	3.49	2.28	4.53	7.42
April	5.72	2.23	.92	10.89	5.28
May	3.51	1.62	5.94	1.95	5.44
June	7.87	7.43	5.20	4.54	6.19
July	7.41	4.10	12.08	10.72	9.80
August	8.13	6.47	3.23	6.47	7.13
September	9.79	5.39	3.95	6.23	8.09
October	3.07	3.30	.65	3.88	2.60
November	7.87	2.65	4.71	4.68	4.13
December	7.37	4.23	6.82	3.55	5.37
Total	86.69	52.07	55.59	70.01	70.43

Elongation patterns.—To check the elongation pattern in a wet spring (1961), five saplings with an average spring flush length of 56 cm. (presumably averaging about 565 nodes as in figure 2) were compared with five saplings whose average spring flush length was 26 cm. (presumably averaging about 190 nodes). The saplings were untreated controls from a girdling-defoliation study described previously (*1*). Length of the spring flush was measured weekly from early February before elongation started until mid-May when elongation was completed in the spring flush on all saplings. The date when elongation started in the bud of the second flush was noted. Average weekly height increments (as percents of the total) of the two sets of trees are given in figure 4.

Saplings with the long spring flush made less of their growth prior to the appearance of the bud of the second flush than saplings with the

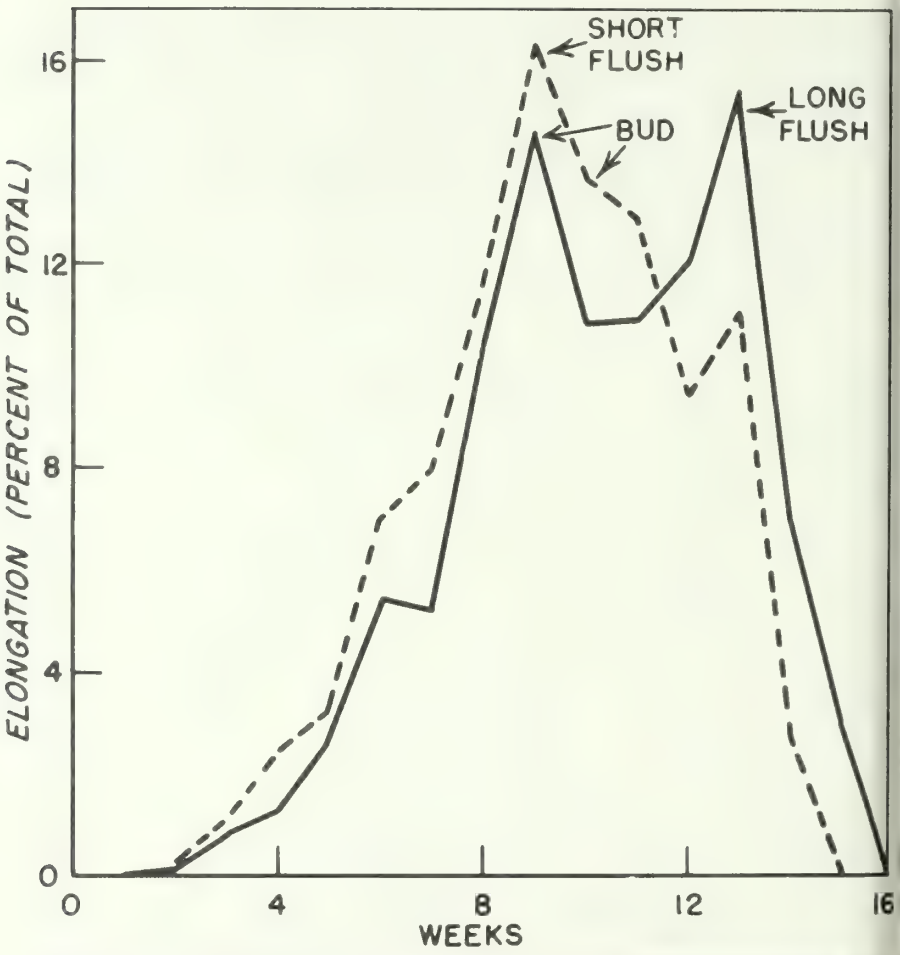

Figure 4. *Periodic growth (expressed as percent of the total) of the spring flush of longleaf saplings with a long spring or a short spring flush.*

short spring flush. A dry April would have more effect on those saplings making a long spring flush, because less of their growth would have occurred prior to the drought.

The reduction in growth rate, which caused the valley in the growth curve of the saplings with the long spring flush, coincided with an unseasonable cold period in early April. Although we do not know what the growth rates would have been had the cold weather not occurred, it seems apparent that the average response to cold by the trees which made a long flush of spring growth was different from that by trees which made a short flush.

Moisture conditions.—In contrast to 1963, moisture conditions were

favorable during elongation of the spring flush in 1964 (table 2). To measure the effects of differences in growing conditions, the length of the spring flush, number of nodes, and internode length were recorded for 57 longleaf saplings in the same manner as in 1963. The data were grouped into classes and plotted in figure 5. The linear correlation coefficient between flush length and number of nodes was 0.83* (as determined from the individual tree data, not the grouped data). Furthermore, grouping and plotting internode elongation over number of nodes gave no suggestion of the curvilinearity found in 1963 and shown in figure 3.

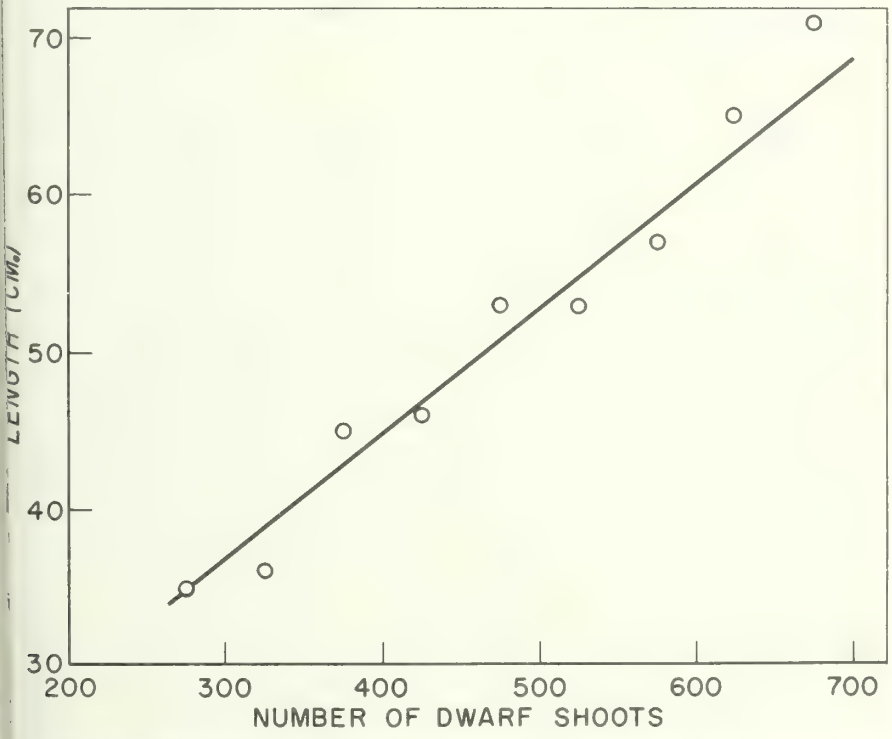

Figure 5. *Relation of flush length to number of dwarf shoots for the first flush of 1964 growth.*

The correlation between flush length and internode elongation was .48* in 1964; it was 0.14 in 1963.

The curvilinear relationship obtained in 1963 between internode length and number of nodes was apparently due to drought in late April and early May. Saplings with a large number of nodes were probably affected more than those with fewer nodes because of the difference in growth patterns discussed in relation to figure 4. Also, saplings with more needles

in the spring flush had greater transpiring surface, which may have caused internal water deficits in the shoot.

Length of a Flush

To determine the relative importance of number of nodes and internode elongation in determining flush length, the third flush in 1963 (summer) and the first in 1964 (spring) were examined. These flushes were chosen because growing conditions were favorable during their formation and elongation. The correlation coefficients were:

Comparison	Spring flush	Summer flush
Length with number of nodes	0.83*	0.88*
Length with internode elongation	.48*	.56*

In the spring flush the multiple correlation coefficient of length (l) with number of nodes (n) and internode elongation (e) with 0.87*. The partial coefficients were about the same magnitude as the simple correlations: $R_{ln.e} = 0.82^*$ and $R_{le.n} = 0.43^*$. The multiple correlation coefficient for the summer flush was $R_{lne} = 0.92^*$, and the partial correlation coefficients were $R_{ln.e} = 0.88^*$ and $R_{le.n} = 0.53^*$. The similarity between the simple and the partial correlation coefficients show that the simple correlations were not materially influenced by intercorrelations.

In the above examples, which were chosen because of favorable environmental conditions, variation in number of nodes explained 77 percent of the variation among trees in the length of the summer flush and 69 percent in the spring flush. Variation in internode elongation explained 30 and 23 percent, respectively, of the variation in length of the two flushes. Thus, changes in number of nodes accounted for almost three times as much variation in flush length as did changes in internode elongation. It should be noted that the estimate of internode elongation was taken from the center of the flush and does not take into account the reduced elongation usually found at either end. Then too, the phyllotaxy was not consistent from tree to tree, and some experimental error may have been introduced into the internode elongation estimate by differences among trees in helical base. The node data were more precise but contained some error because variations in diameter were ignored. In spite of these deficiences, it seems apparent that in these examples more of the variability of flush length originated in the formation of the bud than in bud elongation.

The above examples, however, do not reveal what variation in number of nodes or internode elongation might contribute to the variation in flush length over a range in conditions. There was little difference in

the variation explained by each between the second and the third flush in the 1963 data but there were differences in the relative contribution of each between the spring flush of 1963 and that of 1964.

We do not have additional data on internode elongation; however, the relationships between number of nodes and flush length were examined for the spring flush and for the summer growth[4] in 40 dominant longleaf pine saplings. For the summer growth, the amount of variation in length among trees explained by the number of nodes ranged from a low of 64 percent in 1964 to 81 percent in 1962; the average for all 4 years (1961 through 1964) was 74 percent. For the spring flush, the range was from 30 to 62 percent and an average of 47 percent of the variation in this flush's length was accounted for by variation in node number.

Relations Between Flushes

Correlation coefficients were determined for the relation of length, number of nodes, and internode elongation between the different flushes:

Comparison	Length	Number of nodes	Internode elongation
Between flush 1 and 2	0.43*	0.33*	0.64*
Between flush 1 and 3	.24	.16	.46*
Between flush 2 and 3	.39*	.12	.72*

The correlations in length were mainly due to a correlation in internode elongation. Evidently those factors controlling internode elongation were similar in each flush, but there was little evidence that early flushes influenced the number of nodes produced in subsequent flushes.

Conversely, the second flush did not materially influence the elongation of the first. This result was obtained in a separate study where the effect of the second flush on the spring flush was examined in the spring of 1964 on saplings in the plantation that provided data for length correlations.

Buds of the second flush were removed as soon as they were recognized (between April 20-23) on 10 saplings. The stumps were coated with lanolin immediately after removal of the buds. Each sapling was paired with an untreated control sapling that had approximately the same amount of elongation as the treated sapling at treatment time. Elongations of the spring flush of both treated saplings and controls were measured weekly from April 17 through May 21, when elongation ceased in the

[4] Summation of the lengths of the zones bearing dwarf shoots of all flushes, except the spring flush, of a growing season.

spring flush. At no time was there any significant difference between the treated saplings and the controls, either in pattern or total amount of elongation of the spring flush.

Measurements on the 40 dominant longleaf saplings made it possible to determine the correlations between 1961 summer growth and 1962 spring growth, 1962 summer growth and 1963 spring, and 1963 summer and 1964 spring:

Comparison	Correlation coefficient
1961 summer: 1962 spring	−0.13
1962 summer: 1963 spring	− .35*
1963 summer: 1964 spring	− .26

Although the correlations were statistically significant in only one of the comparisons, it is important that in all three the tendency was for a negative relationship between summer growth and spring growth in the following year.

One might expect the correlation between number of flushes of summer growth and length of spring growth in the following year to be somewhat stronger than the length:length correlation. The number of flushes: spring growth correlations for the different years were:

Comparison	Correlation coefficient
1961 summer: 1962 spring	−0.39*
1962 summer: 1963 spring	− .30*
1963 summer: 1964 spring	− .53*

A still more valid comparison might be that between the number of summer flushes and number of dwarf shoots in the spring flush, because we are primarily concerned with effect of the summer growth on winter-bud formation, and the length of the spring flush is influenced by spring environment. The correlations of number of summer flushes:number of dwarf shoots on the spring flush for the different years were:

Comparison	Correlation coefficient
1961 summer: 1962 spring	−0.59*
1962 summer: 1963 spring	− .29
1963 summer: 1964 spring	− .42*

There was no biological reason evident in the data for the lack of a significant correlation between number of flushes in the summer of 1962 and number of dwarf shoots on the 1963 spring flush.

The correlations show there was a negative relationship between summer growth and growth the following spring; those trees that grew

more in the summer tended to grow less the following spring. Did the same relationship hold within the trees as among them? The relationship between the length of summer growth and the number of dwarf shoots of the spring flush within the trees was determined by using a covariance analysis[5] to remove the variation due to differences in vigor among trees. A significant negative linear regression coefficient indicated that in a year when a tree makes more than its average amount of summer growth the number of dwarf shoots is reduced in the first flush of the next year.

The same type of analysis was employed to see if the spring flush exerted any influence on the second flush in the same year. For 1961-1964, both length:length and the length:dwarf shoot relationships were analyzed. No significant relationship was obtained. It was concluded, therefore, that growth of the second flush is largely independent of spring growth within a tree.

Discussion

It has been shown here that the number of nodes formed in the bud is an excellent index of the elongation potential of the terminal bud. The results also demonstrate the very important relationship between the variation in bud formation and that of flush length. The data strongly support Duff and Nolan's (3) observation that if conditions are favorable during bud formation the length of the resulting flush will usually be large despite the environmental conditions during extension growth. They also note that favorable conditions during extension growth will not usually offset the reduction in flush length attributable to a puny bud that resulted from unfavorable conditions during its formation.

Under weather conditions deemed favorable for both bud formation and extension growth, about three times as much of the variation in flush length among trees was accounted for by differences in the number of nodes than by differences in internode elongation in the longleaf pines studied. Under these conditions, variation in number of nodes explained 7 percent of the variation in length of a summer flush and 69 percent of that in the spring flush. On the average, however, 74 percent of the variation in summer growth and 47 percent of that in the spring flush were accounted for by the variation in node number.

The 1963 data showed how adverse weather, in this case growth, can reduce the growth of trees with a high growth potential and leave those trees with a lower potential relatively unaffected. In 1962, growth rates of trees making a long spring flush appeared to be affected differently

[5] Dr. C. B. Loadholt of the Department of Experimental Statistics, Clemson University, did the covariance analyses.

by a period of cold weather than those making a short flush. These observations illustrate how adverse conditions can differentially affect the growths of individual trees.

The timing of the occurrences was no doubt of importance in both of these instances. Two trees in the same stage of growth, for example, might respond the same to a given adverse weather condition, but their responses might be considerably different if they happened to be in slightly different stages of growth. Many such events probably occur at random, and, although they are of considerable importance in contributing to the variation among trees in a given year, they may tend to average out over a long period. Not all of the responses to adverse weather conditions occur at random, however. Some trees, by virtue of their genetic constitution or their location in the stand, are not able to withstand or recuperate from the effects of adverse weather as well as other trees, and, as a consequence, they are at a competitive disadvantage.

Internode elongation in different flushes were correlated in individual trees. Correlation coefficients were: between flushes 1 and 2, 0.64*; 1 and 3, 0.46*; and 2 and 3, 0.72*. Node number was not as strongly correlated; the respective correlation coefficients were 0.33*, 0.16, and 0.12. Variation in the number of nodes from flush to flush within the tree is therefore viewed as being influenced more by external factors than is internode elongation.

An inverse relationship was observed between the amount of summer growth and the amount of spring growth the following year. The relationship may be one of time. When trees put on more than the average amount of summer growth they may simply have less reserves and time remaining in the growing season for the formation of the winter bud. Conversely, when trees make less than the average amount of summer growth they have more time for winter-bud formation. As a result, the length of the spring flush may be increased. Such relationships would tend to increase the amount of variation in terminal growth from one year to the next, especially in view of the fact that no influence of the spring flush on summer growth was detected.

Literature Cited

Allen, R. M., and Scarbrough, N. M.
1969. Development of a year's height growth in longleaf pine saplings. USDA Forest Serv. Res. Pap. SO-45, 13 pp. South. Forest Exp. Sta., New Orleans, La.

Bannister, M. H.
1962. Some variations in the growth pattern of *Pinus radiata* in New Zealand. New Zeal. J. Sci. 5: 342-370.

Duff, G. H., and Nolan, N. J.
1953. Growth and morphogenesis in the Canadian forest species. I. The controls of cambial and apical activity in *Pinus resinosa* Ait. Can. J. Bot. 31: 471-513.

Duff, G. H., and Nolan, N. J.
1958. Growth and morphogenesis in the Canadian forest species. III. The time scale of morphogenesis at the stem apex of *Pinus resinosa* Ait. Can. J. Bot. 36: 687-706.

Sacher, J. A.
1954. Structure and seasonal activity of the shoot apices of *Pinus lambertiana* and *Pinus ponderosa*. Amer. J. Bot. 41: 749-759.

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Hydrologic Effects of Prescribed Burning and Deadening Upland Hardwoods in Northern Mississippi

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Hydrologic Effects of Prescribed Burning and Deadening Upland Hardwoods in Northern Mississippi

S. J. Ursic[1]

In the South, many unproductive stands of upıd hardwoods are being converted to pine. Direct eding, which is cheaper than planting, generalrequires the baring of mineral soil. Fire is the ost practical way of preparing seedbeds, but ıd managers are increasingly apprehensive about rning where the potential for increasing erosion d surface runoff is high. This paper reports the year effects of a single prescribed burn plus adening of hardwoods on two small watersheds northern Mississippi, where soils are extremely osive.

Rainfall, runoff, and sediment were recorded three small watersheds from 1958 through 63. Two watersheds were then burned, the rdwoods on them were deadened, and loblolly nes were planted. The third watershed was mainined as the untreated control. Relationship beeen each treated watershed and the control were tablished from the pretreatment records. These lationships served as a base for evaluating hydrogic behavior of the watersheds after treatment. ne composition and distribution of materials on e forest floor were also determined before and ter treatment.

The long-term objective of the study is to dermine the hydrologic effects of converting from rdwoods to loblolly pine. The effects of burng and hardwood deadening reported here could e isolated because the treatment increased stormow volumes, and any decreases caused by the nes were negligible during the first 3 years afr planting.

[1] Principal Hydrologist at the Forest Hydrology Laboratory, Oxrd, Miss. The Laboratory is maintained by the Southern Forest periment Station in cooperation with the University of Mississippi. e study was installed with the cooperation of the Soil Conservan Service.

STUDY WATERSHEDS

The study area is on the Upper Coastal Plain in northern Mississippi. The mean annual precipitation of 53.3 inches is fairly well distributed throughout the year. Mean daily temperature is 63.1° F. Average dates of the first and last frosts are November 7 and March 28; thus, length of the frost-free season averages 224 days.

All three watersheds have a history of grazing and burning abuse and have suffered sheet erosion, but no gullies are present. Slopes range up to 10 percent on ridges and up to 45 percent on the hillsides.

Northern Mississippi is underlain by deep unconsolidated strata of sands and clays. Upland soils are typically sandy, but the study area is on the eastern fringe of a loessial blanket. Loess commonly occupies the ridges and upper slopes. Watershed I has Loring silt loam and Providence silt loam (loess) soils on the upper slopes, which cover 65 percent of the 2.56-acre drainage, and Ruston sandy loam on lower slopes, which cover the rest of the area. It has a 49-foot range in elevation from the watershed divide to the measuring flume.

Watershed II has Providence silt loam on the upper slopes, which make up 34 percent of the drainage, and Ruston sandy loam on the remainder, the lower slopes. It covers 2.12 acres and has a 58-foot range in elevation.

Watershed III is all Providence silt loam. It drains 2.13 acres and has a 44-foot range in elevation.

The untreated watershed was selected on the basis of soils. Watershed III with all silt loam (loess) soils and Watershed II with two-thirds of its area covered by sandy loam were treated iden-

tically. Watershed I, intermediate with respect to soils, served as the common control.

Before treatment the tree cover consisted largely of post oak (*Quercus stellata* Wangenh.), hickories (*Carya* spp.), and blackjack oak (*Quercus marilandica* Muenchh.). The stands, which were completely inventoried, contained an average of 215 trees per acre larger than 0.5 inch d.b.h.; half the trees were cull. Basal area per acre averaged 52 square feet, 23 square feet of which were cull (table 1). Merchantable volume was about 570 board feet per acre.

Litter and Herbaceous Vegetation

Watersheds were divided into ¼ acre hexagonal blocks. The distribution of ground cover was determined from two permanent 1-chain transects selected at random bearings from the center of seven blocks on each watershed. A 1-chain tape was stretched tightly along each transect and the cover under each link recorded.

Litter and fermentation layers were sampled separately on two 0.96-square-foot plots at random distances along each transect. There were 28 samples per watershed. Residual amounts of the F layer, after drying and screening, were determined by loss on ignition. Grasses and herbaceous material were clipped 1 inch above the groundline on enlargements (4.8 square feet) of the litter plots.

The forest floor on the three watersheds averaged 0.75 inch in depth. The depth of the A_1 soil horizon averaged 0.81 inch. The 0- to 2-inch soil layer had an average bulk density of 1.07 g. per cc. and contained 3.84 percent organic matte weight. The amount of bare soil exposed aged 1 percent.

METHODS

Watershed Treatment

Watersheds II and III were burned with a backfire on December 19, 1963 (fig. 1). To termine their long-term effects, 1-0 loblolly seedlings were planted on the two burned w sheds on March 12, 1964. The seedlings planted with dibbles at a 6- by 6-foot spacin is assumed that the planting operation and development of the pines through 1966 had hydrologic effect. The watersheds were pla rather than seeded to help ensure a uni stand.

The overstory on the two burned waters was treated on May 13-14, 1964. Undiluted 2 amine was injected into the bases of all s 1 inch in diameter and larger. The remaining s were cut and the stumps mopped with a mi of 2,4-D and 2,4,5-T in diesel fuel on June 1964.

Annual rainfall on the watersheds averaged inches in 1964, 40.5 in 1965, and 50.5 in Deviations from the long-term mean were + −12.8, and −2.8 inches. Thus, after treatment was a wet year, a dry year, and a year with n average rainfall. Rainfall distribution, how was atypical and runoff from the control for of the post-treatment years exceeded the pret ment mean. In 1965, no runoff occurred March 29. Monthly rainfall and runoff during

Table 1.—*Average number of trees and basal area per acre*

Watershed No.	Trees[1]			Basal area[1]		
	Growing stock	Cull[2]	Total	Growing stock	Cull[2]	Total
	Number			*Square feet*		
I	98	84	182	24	21	45
II	108	120	228	25	26	51
III	117	117	234	38	21	59
Mean	108	107	215	29	23	52

1 Includes all stems over 0.5-inch d.b.h.
2 All blackjack oak considered cull.

Figure 1.—*The watersheds were burned with a slow backfire on December 19, 1963.*

udy period are given in Appendix tables 8 and

ıstrumentation

Three-foot H-flumes equipped with water-stage ecorders measure runoff from the watersheds *6, pp. 22-24*). Deposited sediment is collected in ɔncrete approach sections. Samples for suspended ediment determinations are obtained with a Coshton wheel sampler (*3*).

The three watersheds are contiguous. A recordg rain gage is located near the center of the udy area, and six nonrecording gages form a etwork over the area.

alibration

The paired watershed approach was taken. Wilm [7, 8) presented analytical methods for determining e adequacy of calibration of annual discharge ɔm paired watersheds, and Kovner and Evans 2) extended them. Reinhart (*4*) applied these ıethods to monthly and seasonal yields and to ɹak and low flows. Runoff from the study watereds was largely ephemeral, and main reliance as placed on calibration relationships based on idividual runoff events. The adequacy of such alibrations has been reported (*5*).

Pretreatment relationships among watersheds ere developed for the volumes of stormflow and to measures of their distribution—instantaneous peak discharge and the portion of stormflow volume estimated as overland flow. All events which produced runoff on either the control or a treated watershed were included in the stormflow-volume analyses. A storm was defined as a precipitation event bounded by rainless intervals of at least 6 hours. The calibration and post-treatment equations for the three variables are summarized in Appendix tables 10, 11, and 12.

Analyses

The linear regression model to describe relationships between watersheds during the calibration period is $Y = a + bX$. The calibration regressions were compared by covariance analysis with the regressions developed from data collected during each year after treatment. The null hypothesis is that the two regressions are estimates of the same general equation. If this hypothesis is rejected, the conclusion is that the relation between phenomena on the control watershed (X) and a treated watershed (Y) has changed, and that two equations are required to describe the relations before and after treatment.

Covariance analysis can determine whether the change is some function of X or is best expressed as a constant for all values of X (*1*). The first step is to test for differences in slope. If slopes differ, the magnitude of change varies with X.

When slopes were found to be significantly different, each individual measurement after treatment was subjected to a t-test, and the probability of the magnitude of the change determined. Repeated use of the t-test, comparing successive post-treatment observations against the same prediction equation, fails to meet statistical standards because requirements for independence are not met. However, such comparisons are informative and were made. The t-tests were for increases only. Thus, only one end of the probability curve was considered.

If the slopes of the equations do not differ, differences in level can be tested. Here again, since the critical value for testing equal levels cannot be precisely determined, the hypothesis of equal slopes cannot be tested without some probability of error. However, to aid interpretation where a change in level was indicated, the two equations were adjusted to a common slope and the average change determined. The average change was also expressed as a percentage of the pretreatment mean. All testing was at the 5-percent level of confidence.

Where variances of regressions differed significantly and a change in level was indicated, a conservative test was applied. The largest variance and its degrees of freedom were used in the F tests for differences in slope and level. While true differences in pre- and post-treatment variances might exist, none of the conclusions regarding change in level was altered as a result of this procedure.

Ratios of sediment yields before and after treatment were also compared.

TREATMENT EFFECTS

Runoff

Stormflows, overland flows, and peak discharges increased on both watersheds during the first 3 years after treatment. There was little indication that the increases in each of the runoff variables lessened during this time.

Annual after-treatment regressions are evaluated for each of the three runoff variables in the sections following. The most reliable indicators of change are the regressions developed from data collected during all 3 years after treatment. Without exception, a change in slopes was indicated for the regressions based on 3-year data.

Stormflow volumes. – Twenty-four percent of t events on Watershed II and 27 percent of tho on Watershed III during 1964-1966 produced stor flow volumes significantly higher than predict (table 2).

Watershed II produced 4 area-inches more w ter than expected (a 30-percent increase), a Watershed III produced 7 more area-inches (a 2 percent increase) during the 3 years. A few k storms produced a large proportion of the increas In 1964, a 4.3-inch August storm accounted for percent of the annual increase from Watershed and 38 percent of the annual increase from Wat shed III. Similarly in 1966, a 5-inch storm in Fe ruary produced 70 percent of the annual increa from Watershed II and half the increase from W tershed III. Thus, the treatment applied could co tribute substantially to both summer and wint floods.

Overland flow.—Overland flow was defined the volume of stormflow represented by the pa of a hydrograph above a straight line drawn b tween the beginning of a rise and the point maximum curvature on the recession.

Estimated overland flows were less sensiti to treatment than stormflows. Fourteen perce of the events on Watershed II and 17 percent those on Watershed III during 1964-1966 we significantly higher than predicted (table 3 Watershed II produced 22 percent more overla flow during the 3 years (1.89 area-inches) a Watershed III produced 27 percent more (3. area-inches). Seventy-one percent of the 3-ye increase from Watershed II and 48 percent that from Watershed III resulted from two storms August 15, 1964, and February 9, 1966.

Peak discharges.—Analyses were confined to ru off events which produced instantaneous pe flows $\geq$ 0.05 c.f.s. (cubic feet per second) p acre on the control or a treated watershed.

Peak flows were higher than predicted by si nificant amounts for 23 percent of the runo events on Watershed II and for 25 percent of tho on Watershed III (table 4). The total 3-year i crease was 36 percent for Watershed II and 2 percent for Watershed III.

On Watershed II, peak flows were not signif cantly larger than predicted in 1966. Treatme effect may have been declining, but the regressio was based on only seven events.

Table 2.—*Treatment effects on volumes of stormflow*

Year	Change in regression: Slope	Level	Events	Events significantly higher than predicted	Total increase[1]	
			No.	*Pct.*	*Area-inches*	*Pct. of predicted*
			Watershed II			
1964	*	...	29	21	1.21	22
1965	*	...	13	31	1.01	22
1966	*	...	11	27	1.84	54
1964-1966	*	...	53	24	4.06	30
			Watershed III			
1964	*	...	31	19	2.72	22
1965	...	*	14	(2)	1.34	16
1966	*	...	11	54	2.95	46
1964-1966	*	...	56	27	7.01	26

1 Sum of measured minus predicted values.

2 The average difference between the pre- and post-treatment regressions adjusted to a common slope was 0.098 area-inch. This increase was 33 percent of the pretreatment mean.

* Statistically significant at 5-percent level.

Table 3.—*Effect of treatment on volumes of overland flow*

Year	Change in regression: Slope	Level	Events	Events significantly higher than predicted	Total increase[1]	
			No.	*Pct.*	*Area-inches*	*Pct. of predicted*
			Watershed II			
1964	*	...	22	9	0.65	21
1965	*	...	10	20	.32	10
1966	*	11	18	18	.93	38
1964-1966	*	...	43	14	1.89	22
			Watershed III			
1964	*	...	26	12	1.64	28
1965	n.s.	n.s.	10	0	.11	2
1966	*	...	11	45	2.13	54
1964-1966	*	...	47	17	3.89	27

1 Sum of measured minus predicted values.

* Statistically significant at 5-percent level.

Table 4.—*Treatment effects on peak discharges*

Year	Change in regression: Slope	Level	Events	Events significantly higher than predicted	Total increase[1]	
			No.	*Pct.*	*C.f.s./acre*	*Pct. of predicted*
			Watershed II			
1964	*	...	13	38	1.57	53
1965	*	...	10	20	.64	31
1966	n.s.	n.s.	7	0	.23	13
1964-1966	*	...	30	23	2.45	36
			Watershed III			
1964	*	...	18	22	1.38	33
1965	*	...	10	20	.40	15
1966	n.s.	*	8	(2)	.76	34
1964-1966	*	...	36	25	2.54	28

1 Sum of measured minus predicted values.
2 The average difference between the pre- and post-treatment regressions adjusted to a common slope was 0.092 c.f.s. per acre. This increase was 44 percent of the pretreatment mean.
* Statistically significant at 5-percent level.

Sediment

The relationship of annual sediment production among watersheds was fairly consistent during the pretreatment years. The yields from Watershed II were approximately twice those from the control, while the yields from Watershed III approximated those from the control (fig. 2). These ratios were applied to predict yields in the post-treatment years, and the increases were calculated as measured minus predicted values.

Sediment-yield increases the first year averaged 428 pounds per acre (table 5). Yields from Watershed III continued higher than expected during the second and third years. The increase from Watershed II was largely confined to the first year.

Average annual sediment concentrations for Watershed III also increased markedly during the first and second years after burning and hardwood control (fig. 3), but returned to pretreatment levels the third year. Thus, both runoff and the concentrations of sediment per unit of runoff from Watershed III increased as a result of watershed treatment. Data for Watershed II were too variable to demonstrate changes in average concentrations of sediment.

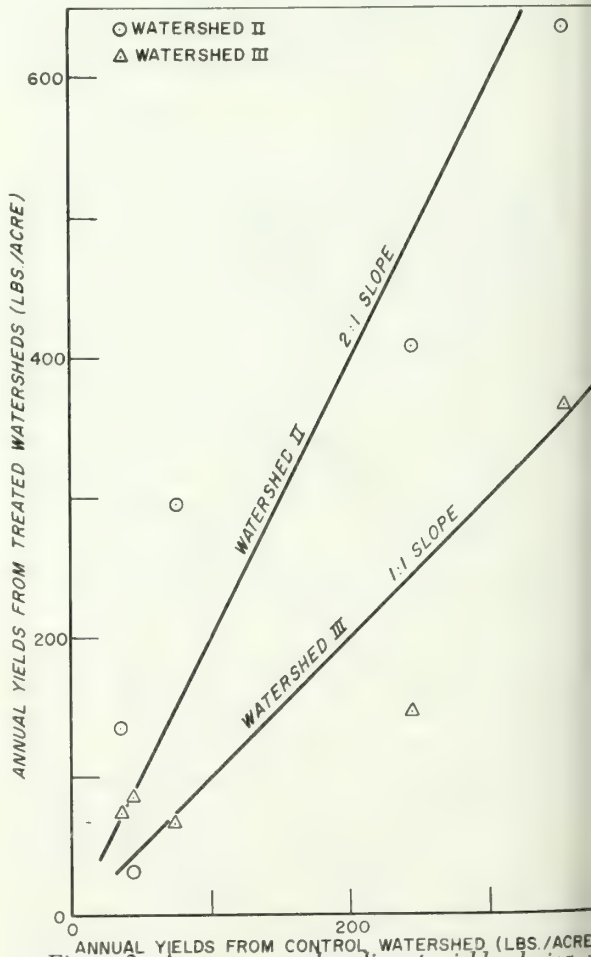

Figure 2.—*Average annual sediment yields during treatment years.*

Table 5.—*Sediment yields before and after treatment*

Watershed	Preburn means	Postburn yields			Increase over prediction
		Measured	Expected	Increase	
	Pounds per acre–dry weight				*Percent*
		1964			
I Control	151	397	...	...	...
II	300	1,179	794	385	48
III	148	868	397	471	119
		1965			
I Control		180	...	...	...
II		390	360	30	8
III		408	180	228	127
		1966			
I Control		58	...	...	...
II		84	116	Decrease	...
III		128	58	70	121

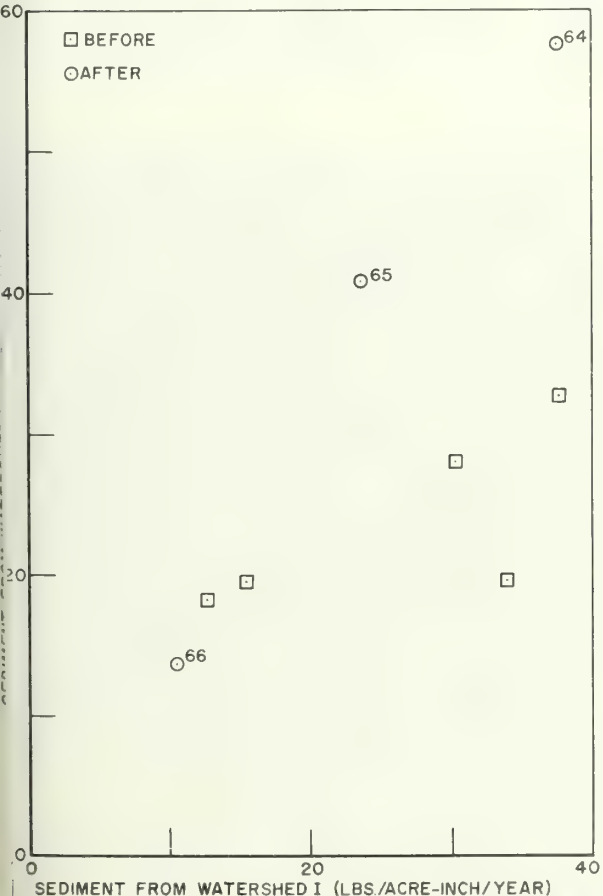

Figure 3.—*Average annual sediment concentrations on ontrol and Watershed III before and after treatment.*

Vegetation

The L (litter) layer on the two treated watersheds prior to the burn weighed an average of 1,500 pounds per acre; the F (fermentation) layer weighed 6,870 pounds per acre (table 6) (fig. 4). The fire consumed the L layer but reduced the weight of the F layer by less than 1 percent (fig. 5). Leaves from the dying hardwoods restored the L layer during the first year after burning, but 60 percent of the F layer disintegrated during this time. Thus, the loss of forest floor material during the first year after burning was greater than during the burn itself.

The total weight of the forest floor 1 year after the burn averaged 55 percent of the preburn weight; after 3 years, it averaged 51 percent of the preburn weight.

Grasses and forbs began to invade the area during the second spring after burning. The ovendry weight of this vegetation, clipped 1 inch above the groundline in December 1965, averaged 1,250 pounds per acre. It increased to an average of 1,885 pounds per acre by October 1966 (fig. 6).

Sprouts and stems less than 1 inch in diameter increased from 150 per acre prior to the burn, to 6,644 per acre 2 years after the burn, and to 11,020 per acre 3 years after burning. The planted loblolly pines are competing successfully with this growth.

Table 6.—*Weight of the forest floor before and after the December 1963 burn*

Watershed	Preburn	February 1964	Postburn		October 1966
			December 1964	December 1965	
	Pounds per acre–ovendry				
			L(A_{oo}) layer		
II	1,416	(1)	1,633	281	(1)
III	1,588	(1)	2,208	748	(1)
Means	1,502	...	1,920	515	...
			F (A_o) layer		
II	6,135	5,928	2,039	4,059	4,111
III	7,605	7,741	3,374	5,279	4,432
Means	6,870	6,834	2,706	4,669	4,271
			L + F layers		
II	7,551	5,928	3,672	4,340	4,111
III	9,193	7,741	5,582	6,028	4,432
Means	8,372	6,834	4,627	5,184	4,271

1 Included with F layer.

Figure 4.—*Forest floor just before burning.*

Figure 5.—*The fire removed the L-layer, which consisted largely of the current leaf fall, but it reduced the weight of the F-layer by less than 1 percent.*

Figure 6.—*Three years after the burn the weight of the forest floor averaged one-half the preburn weight. The ovendry weight of grasses and forbs averaged 1,885 pounds per acre.*

Burning exposed mineral soil on 13 percent of the ground surface of the watersheds (table 7). Three years after the fire, 95 percent of the watershed surfaces had some form of cover. Needles cast by the pine should accumulate rapidly during the next few years. Thus, any future effects of treatment may be lessened by the planting of the pine.

SUMMARY

After 6 years of calibration, two small watersheds occupied by depleted hardwood stands were burned in December 1963. A slow backfire consumed the L layer. It reduced the F layer less than 1 percent. The hardwoods were treated with a herbicide in May 1964. A third unburned watershed was maintained as a control.

During the first 3 years after treatment, about one-fourth of the stormflows were increased by significant amounts. Annual increases ranged from 1 to 3 area-inches—increases of 16 to over 50 percent. Estimated overland flows and peak discharges also increased. Two large rains caused a large proportion of the increases. Treatment effects did not diminish during the first 3 years.

Table 7.—*Composition of cover before and after the December 1963 burn and during the recovery period*

Cover class	Watershed	Preburn	February 1964	Postburn		October 1966
				December 1964	December 1965	
		Percent of ground surface occupied				
Grasses, forbs	II	7	2	8	14	12
	III	2	0	4	8	8
Forest floor	II	92	74	74	61	69
	III	95	83	83	80	82
Bare soil	II	0	17	12	15	8
	III	2	11	8	7	2
Moss, lichens, other	II	1	7	6	10	11
	III	1	6	5	5	8

During the first post-treatment year, sediment production from one watershed exceeded the expected value by 48 percent. On the other watershed, it was more than double the predicted value. The increases averaged about 400 pounds per acre. Sediment production continued high from the watershed with loess soils during the second and third years. On the sandy watershed the increase was largely confined to the first year.

The fire removed 18 percent of the organic matter making up the forest floor. Despite the contribution from the dying hardwoods, an additional 26 percent of the preburn weight was lost during the first year. Three years after treatment, the weight of forest floor material averaged one-half the preburn weight.

Sediment increases resulting from the light winter burn of ungullied, poor-quality upland hardwoods and the subsequent deadening of the hardwoods were not alarming. They appeared to be decreasing over the first 3 years and the development of the planted pine should soon practically eliminate soil movement. The increase in runoff, which persisted for 3 years, however, suggests that stand conversion procedures including fire should be used with caution in the hilly uplands of north Mississippi, where flood abatement is an important objective of land management.

LITERATURE CITED

1. Freese, F.
   1964. Linear regression methods for forest researc
   USDA Forest Serv. Res. Pap. FPL-17, 1
   pp. Forest Prod. Lab., Madison, Wis.
2. Kovner, J. L., and Evans, T. C.
   1954. A method for determining the minimum dur
   tion of watershed experiments. Amer. Ge
   phys. Union Trans. 35: 608-612.
3. Parsons, D. A.
   1955. Coshocton-type runoff samplers. USDA Ag
   Res. Serv. ARS-41-2, 16 pp.
4. Reinhart, K. G.
   1958. Calibration of five small forested watershe
   Amer. Geophys. Union Trans. 39: 933-936.
5. Ursic, S. J., and Popham, T. W.
   1967. Using runoff events to calibrate small forest
   catchments. Int. Union Forest. Res. Orga
   14th Congr. Proc. 1: 319-324.
6. USDA Agricultural Research Service.
   1962. Field manual for research in agricultural hydr
   logy. USDA Agr. Handbook 224, 215 pp.
7. Wilm, H. G.
   1944. Statistical control of hydrologic data from e
   perimental watersheds. Amer. Geophys. Uni
   Trans. 1943: 618-622.
8. Wilm, H. G.
   1949. How long should experimental watersheds
   calibrated? Amer. Geophys. Union Trans. 3
   272-278.

APPENDIX

Table 8.—*Average rainfall by months during study period*[1]

Month	1958	1959	1960	1961	1962	1963	1964	1965	1966
	Inches								
January [2](5.04)	2.64	3.98	5.33	0.76	6.54	1.35	4.22	4.27	2.86
February (4.22)	1.66	4.51	3.68	8.13	7.32	2.50	2.96	8.74	8.55
March (5.71)	4.69	3.07	5.79	12.75	3.67	5.59	9.08	9.04	1.68
April (4.88)	10.52	3.78	2.07	2.65	5.85	6.49	9.91	1.06	7.09
May (4.38)	3.01	3.58	2.64	3.84	1.71	1.97	1.66	2.54	7.01
June (4.34)	8.63	4.92	3.57	1.78	6.82	2.07	1.90	.77	2.83
July (4.26)	5.55	6.33	.44	2.96	3.72	9.77	8.73	1.88	3.24
August (3.61)	2.59	1.90	2.71	3.00	1.78	3.20	6.56	3.67	1.34
September (3.32)	11.21	5.71	3.90	1.74	3.80	3.39	5.13	4.25	5.51
October (2.98)	.73	4.45	4.88	1.51	1.54	0	2.32	.87	2.26
November (4.54)	3.56	3.21	3.19	9.96	2.35	3.77	4.24	1.38	1.68
December (6.02)	1.71	5.61	4.49	10.48	2.20	5.19	8.43	2.03	6.46
Totals (53.30)	56.50	51.06	42.69	59.55	47.30	45.30	65.14	40.51	50.51

1Averages for three watersheds.
2 Long-term means at University, Mississippi, shown in parentheses.

Table 9.—*Runoff by month during study period*

Month	Watershed	1958	1959	1960	1961	1962	1963	1964	1965	1966
		Area-inches								
January	I	0.00	0.61	0.43	0.00	2.21	0.00	0.30	0.70	0.00
	II	.00	.31	.05	.00	.60	.00	.24	.40	.00
	III	.20	1.49	1.00	.00	2.12	.00	.28	1.12	.00
February	I	.00	.98	.33	2.20	2.63	.00	.24	3.42	1.92
	II	.00	.46	.04	1.62	1.94	.00	.06	2.74	2.84
	III	.00	1.32	.67	3.30	2.61	.00	.33	4.56	4.13
March	I	.30	.04	1.89	5.30	.33	.70	3.23	3.46	.07
	II	.00	.01	1.05	3.15	.06	.57	2.08	2.56	.01
	III	.63	.16	2.37	5.83	.52	.75	3.78	4.32	.29
April	I	3.39	.07	.00	.21	1.93	.96	3.17	.00	2.04
	II	1.93	.00	.00	.00	1.25	.61	1.29	.00	1.28
	III	4.27	.19	.00	.31	2.06	1.19	3.43	.00	2.27
May	I	.09	.00	.02	.00	.00	.00	.00	.00	1.14
	II	.01	.00	.00	.00	.00	.00	.00	.00	.72
	III	.04	.00	.03	.00	.00	.00	.00	.00	1.73
June	I	.48	.04	.00	.00	.06	.00	.00	.00	.02
	II	.31	.00	.00	.00	.01	.00	.00	.00	.00
	III	.63	.02	.01	.00	.03	.00	.00	.00	.00
July	I	.01	.01	.00	.00	.00	.00	.02	.00	.00
	II	.00	.00	.00	.00	.00	.00	.01	.00	.00
	III	.01	.02	.00	.00	.00	.00	.07	.00	.00
August	I	.01	.00	.00	.00	.00	.00	.52	.00	.00
	II	.00	.00	.00	.00	.00	.00	1.17	.00	.00
	III	.00	.00	.00	.00	.00	.00	1.63	.00	.00
September	I	1.41	.04	.00	.00	.00	.00	.06	.00	.00
	II	1.40	.01	.00	.00	.00	.00	.15	.00	.00
	III	1.72	.13	.00	.00	.00	.01	.23	.00	.00
October	I	.00	.06	.00	.00	.00	.00	.00	.00	.00
	II	.00	.01	.00	.00	.00	.00	.00	.00	.00
	III	.00	.03	.00	.00	.00	.00	.00	.00	.00
November	I	.01	.00	.00	.47	.00	.00	.08	.00	.00
	II	.00	.00	.00	.40	.00	.00	.04	.00	.00
	III	.00	.00	.00	.34	.00	.00	.76	.00	.00
December	I	.00	.86	.21	3.60	.04	.29	2.99	.00	.38
	II	.00	.47	.01	2.06	.00	.24	2.36	.00	.39
	III	.00	1.13	.11	3.31	.00	.13	4.51	.00	.89
Totals	I	5.70	2.73	2.89	11.80	7.21	1.96	10.62	7.59	5.56
	II	3.65	1.28	1.17	7.23	3.86	1.43	7.42	5.70	5.23
	III	7.50	4.48	4.21	13.09	7.36	2.10	15.02	9.99	9.30

Table 10.—*Calibration and post-treatment regressions relating stormflows on the control (X) and treated (Y) watersheds*

Year	Regression	Number of events	Mean yields	
			$\bar{x}$	$\bar{y}$
			— — — — *Area-inches* — — — —	
Watershed II				
Prediction equation				
1958-1963	$0.66579X - 0.02816$	89	0.21737	0.11656
	$S_{y.x}^2 = 0.00470$, $S_x^2 = 10.93882$, $r = 0.960$			
Post-treatment equations				
1964	$0.82370X - 0.03792$	29	0.32519	0.22994
1965	$.91549X - .09608$	13	.58383	.43840
1966	$1.07387X - .06755$	11	.50579	.47560
1964-1966	$.91620X - .05834$	53	.42611	.33206
Watershed III				
Prediction equation				
1958-1963	$1.11008X + 0.01602$	96	0.25202	0.29578
	$S_{y.x}^2 = 0.00882$, $S_x^2 = 14.77702$, $r = 0.978$			
Post-treatment equations				
1964	$1.26013X + 0.05225$	31	0.34251	0.48386
1965	$1.19289X + .06710$	14	.54213	.71380
1966	$1.52514X + .07441$	11	.50579	.84581
1964-1966	$1.28236X + .06809$	56	.42449	.61244

Table 11.—*Calibration and post-treatment regressions relating overland flows on the control (X) and treated (Y) watersheds*

Year	Regression	Number of events	Mean yields	
			$\bar{x}$	$\bar{y}$
			— — — — *Area-inches* — — — —	
	Watershed II			
Prediction equation				
1958-1963	0.84871X — 0.01310	86	0.12412	0.09224
	$Sy.x^2 = 0.00373$, $Sx^2 = 3.02547$, $r = 0.935$			
Post-treatment equations				
1964	1.06616X — .02285	22	0.18104	0.17017
1965	1.07818X — .06708	10	.37317	.33526
1966	1.27516X — .04792	11	.27905	.30791
1964-1966	1.12675X — .03878	43	.25079	.24380
	Watershed III			
Prediction equation				
1958-1963	1.16272X + 0.03304	94	0.14297	0.19927
	$Sy.x^2 = 0.01067$, $Sx^2 = 4.13274$, $r = 0.922$			
Post-treatment equations				
1964	1.49535X + 0.04039	26	0.16806	0.29170
1965	1.01594X + .09922	10	.37317	.47834
1966	1.74982X + .06313	11	.27905	.55142
1964-1966	1.44226X + .04940	47	.23768	.39220

Table 12.—*Calibration and post-treatment regressions relating peak discharges on the control (X) and treated (Y) watersheds*

Year	Regression	Number of events	Mean yields	
			$\bar{x}$	$\bar{y}$
			----- *C.f.s./acre* ----	
	Watershed II			
Prediction equation				
1958-1963	0.93839X — 0.01793	34	0.21638	0.18512
	$Sy.x^2 = 0.00209$, $Sx^2 = 1.38659$, $r = 0.974$			
Post-treatment equations				
1964	1.42822X — 0.02465	13	0.26078	0.34780
1965	1.40170X — .06425	10	.23874	.27039
1966	.93100X + .01742	7	.29324	.29043
1964-1966	1.27188X — .02336	30	.26101	.30861
	Watershed III			
Prediction equation				
1958-1963	0.86838X + 0.05568	49	0.17757	0.20988
	$Sy.x^2 = 0.00223$, $Sx^2 = 1.89121$, $r = 0.965$			
Post-treatment equations				
1964	1.36681X + 0.03235	18	0.20098	0.30705
1965	1.20898X + .01438	10	.23874	.30301
1966	1.03985X + .10566	8	.25993	.37594
1964-1966	1.24131X + .04248	36	.22457	.32124

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Small Hardwoods Reduce Growth of Pine Overstory

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Southern Forest Experiment Station
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Small Hardwoods Reduce Growth of Pine Overstory

Charles X Grano

Dense understory hardwoods materially decreased the growth of a 53-year-old and a 47-year-old stand of loblolly and shortleaf pines. Over a 14-year period, hardwood eradication with chemicals increased average annual yield from the 53-year-old stand by 14.3 cubic feet, or 123 board-feet per acre. In the 47-year-old stand the average annual treatment advantage was 32.6 cubic feet, or 342 board feet per acre, over an 11-year period.

Sawtimber stands of loblolly and shortleaf pine (*Pinus taeda* L. and *P. echinata* Mill.) frequently have dense understories of small hardwoods. In uplands in the South, soil moisture is seldom sufficient throughout the growing season for maximum pine growth, and understory hardwoods compete significantly for the limited amount of soil moisture. In midsummer in southern Arkansas, water was lost about 25 percent faster on plots with hardwoods left in place than on those with hardwoods removed (*6*).

Should these understories be eradicated or should they be ignored? To make the correct decision, the land manager must know to what extent they impair the growth of the pines above. Experiments to measure growth effects, however, have produced contradictory results. Eradication of understory hardwoods by burning had no effect on the diameter growth of 60-year-old loblolly pine in South Carolina (*2*). In Tennessee, Russell found that control of understory hardwoods failed to speed the growth of pole-size loblolly (*4*). Likewise, in South Carolina, McClay reported no improvement in diameter growth of 13-inch loblolly pine after 5 years of hardwood control (*3*). He cautioned that conclusive comparisons could not be made until after several years of low rainfall. On the other hand, in the Ouachita Mountains of Arkansas, Bower and Ferguson showed that the removal of 33 square feet of hardwood understory basal area increased the growth of a shortleaf pine overstory by 31 percent (*1*). The improvement in overstory growth was smaller when only part of the understory was removed.

This paper presents the results of two long-term studies in stands of loblolly and shortleaf pine sawtimber. One study, in Bradley County, Arkansas, was continued for 14 years. The other, near Crossett, Arkansas, was started 4 years before the Bradley test. Two plots were destroyed by a tornado soon after establish-

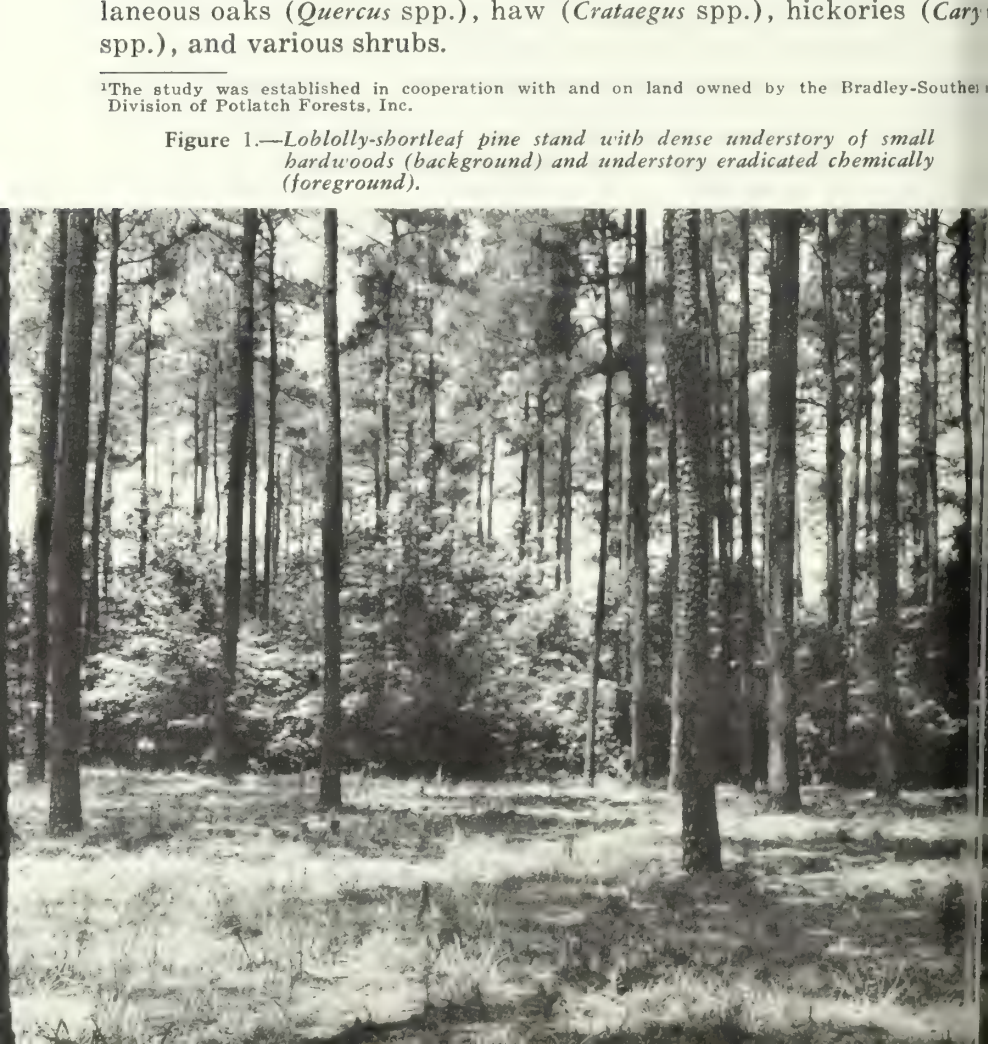
ment, but four remaining plots were remeasured for 11 years. The weather conditions in 18 calendar years are represented by the two studies combined.

METHODS

The Bradley study was established in a 53-year-old pine stand in 1955.[1] The stand was even-aged and well-stocked. Loblolly pine accounted for 88 percent of the pine stems. Soil is Beauregard, a forested coastal-plain series. Because of gently rolling topography all the experimental plots have good surface drainage. Site index ranges from 74 to 78 (at age 50). When the study was started a dense understory of small hardwoods on all plots averaged about 9,000 plants per acre (fig. 1). Southern red oak (*Quercus falcata* Michx.) and sweetgum (*Liquidambar styraciflua* L.) made up 3 percent of the understory by number. The remainder consisted of blackgum (*Nyssa sylvatica* Marsh.), sumac (*Rhus* spp.), elm (*Ulmus* spp.), red maple (*Acer rubrum* L.), dogwood (*Cornus* spp.), miscellaneous oaks (*Quercus* spp.), haw (*Crataegus* spp.), hickories (*Carya* spp.), and various shrubs.

[1]The study was established in cooperation with and on land owned by the Bradley-Southern Division of Potlatch Forests, Inc.

Figure 1.—*Loblolly-shortleaf pine stand with dense understory of small hardwoods (background) and understory eradicated chemically (foreground).*



There were two treatments. In one, all hardwoods and shrubs were eradicated. In the other, all understory vegetation was left in place. Each treatment was replicated three times in a randomized block design. Plots were 1/4 acre in size. Each was surrounded by a 0.5-chain isolation strip that was treated in the same way as the plot.

Hardwoods and other broad-leafed vegetation were removed by cutting all that were over head high and wetting the top and sides of the stumps with a 5-percent oil solution of 2,4,5-T. Those under head high were given a foliar spray of a 2-percent water emulsion of 2,4,5-T applied with a hand sprayer. Today, cheaper and more efficient methods of chemical control are available.

To keep hardwoods from resprouting, plots were resprayed every 2 or 3 years with the water emlusion (fig. 1). Hardwoods on the three control plots were left undisturbed and were inventoried at 5-year intervals. At the start, all plots were thinned to a residual overstory basal area of 75 square feet and to a volume of approximately 2,330 cubic feet per acre. An average of 87 pines per acre was left on the control plots and 90 on the treated plots.

The pines were measured yearly to determine changes in basal area and board-foot volume. The study was extended for 14 years to measure responses to a wide range of rainfall patterns and totals. Water deficiencies during the growing season (May through October) were computed, because they have been shown to relate more meaningfully to growth than does total annual rainfall (5).

The Crossett study was identical to the Bradley study with respect to objectives, treatment, pine species, understory hardwood species, plot size, and number of replications. It differed in time of initiation, location, site quality, stand age, and pine stocking.

It was established in 1951 by the USDA Forest Service in cooperation with the Crossett Company on land now owned by the Georgia-Pacific Corporation. The plots were located in Ashley County, Arkansas, 27 miles southeast of the Bradley area. Soil is Lexington silt loam. Site index is 88 (at age 50). When the study was established the even-aged loblolly-shortleaf pine stand was 47 years old and had a per-acre stocking of 132 trees, 103 square feet of basal area, and 3,218 cubic feet of wood volume. In the understory a thick cover of small hardwoods and woody shrubs averaged 5,590 plants per acre. The hardwoods and shrubs were completely eradicated on three plots, but were left intact on three control plots.

RESULTS

In the Bradley study hardwood numbers per acre on control plots decreased from 8,777 to 5,222 (fig. 2). Hardwood density increased, however, because average stem diameters increased from 0.6 inch in 1955 to 1.1 inches in 1968. Understory basal area increased from 18.4 square feet per acre in 1955 to 32.7 square feet in 1968. It seems safe to assume, therefore, that the demand of understory hardwoods for soil moisture did not diminish during the study.

From the start, the average periodic cubic growth per year was greater on the treated plots, but not always to a significant degree (fig. 3). In 1964, the periodic cubic-foot growth of the plots without hardwoods proved to be significantly greater than the control yields, starting a firm trend that continued un

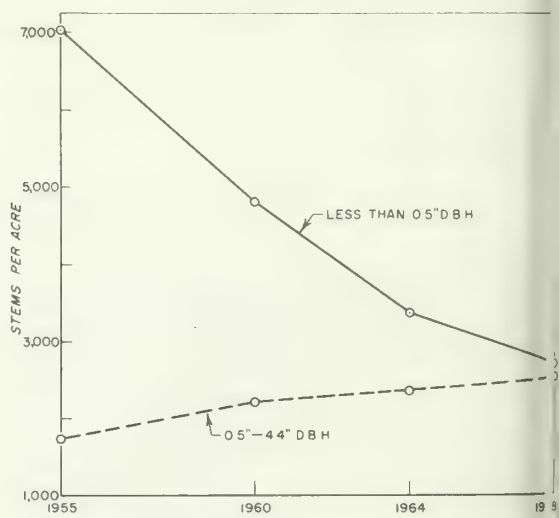


Figure 2.—*Changes in numbers of hardwoods per acre on control plots.*

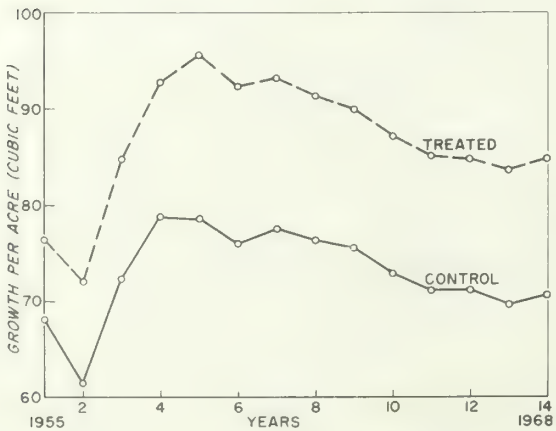
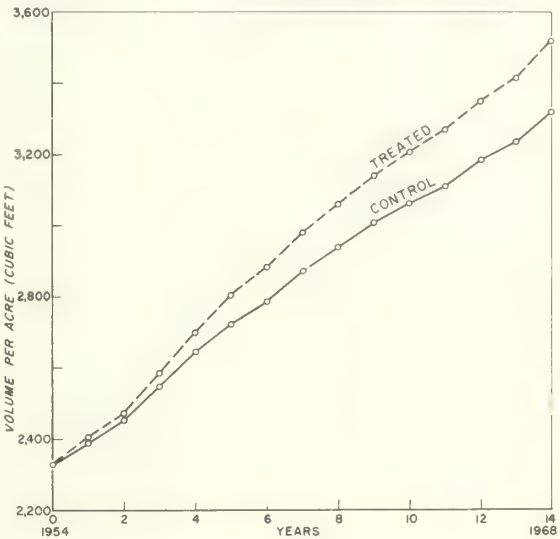


Figure 3.—*Periodic annual cubic growth per acre.*

liminished to the termination of the study in 1968. Periodic annual oard-foot and basal area growth differences were also signifiantly higher on treated than on untreated plots from 1964 onward.

At the start of the study both treatments were similar in basal rea and cubic volume. The cumulative growth trend lines diverged arly, indicating a rapid esponse to hardwood emoval. The advanage of treatment inreased continuously to he close of the study figs. 4 and 5). In the eginning the treated lots had a small ad-



gure 4.—*Stand in cubic feet per acre at end of each growing season.*

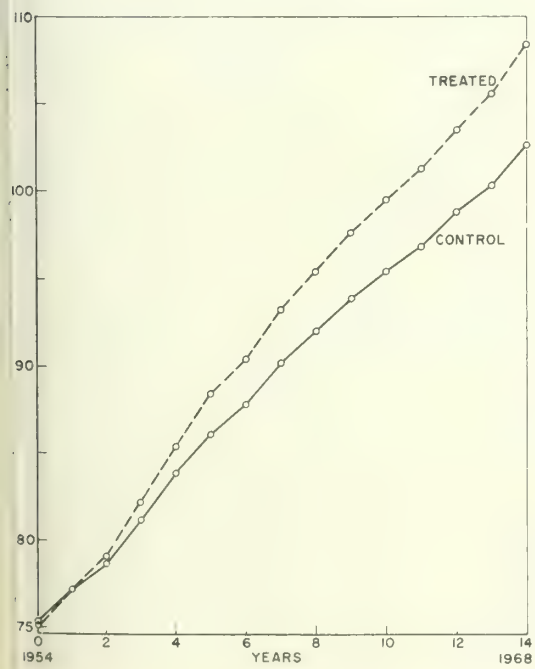


Figure 5.—*Stand in basal area per acre at end of each growing season.*

vantage over the controls in board-foot stocking. The respons to hardwood removal, however, more than quadrupled the initia advantage in favor of the treated areas (fig. 6).

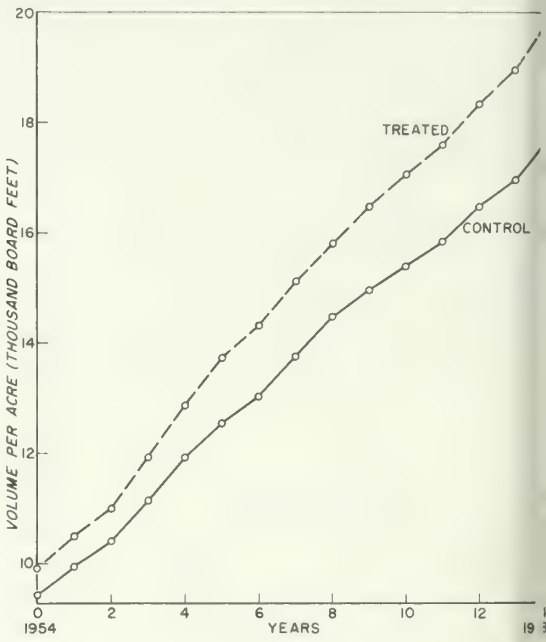


Figure 6.—*Stand in board feet per acre at end of each growing season.*

Average annual growth per acre during the study was:

Treatment	Cubic feet[1]	Board feet[2]	Square fee of basal ar
Hardwoods removed	84.9	713	2.4
Hardwoods left	70.6	590	2.0
Difference	14.3	123	.4

[1]All trees included.
[2]International ¼-inch rule. Trees 9½ inches d.b.h. and larger.

In 14 years the total growth advantage per acre attributab to understory hardwood removal amounted to 200 cubic feet 1,720 board feet. These differences were obtained in stands we stocked to begin with and heavily stocked when the test ende When the study began the treated plots had an average bas area of 75.1 square feet and a volume of 2,328 cubic feet, or 9,90 board feet per acre. At the close of the test these averages ha increased to 108.3 square feet, 3,517 cubic feet, and 19,891 boar feet. By contrast, the beginning and ending per-acre stockings f the controls were 75.3 and 102.6 square feet, 2,330 and 3,31 cubic feet, and 9,431 and 17,687 board feet.

In general, current annual cubic-foot growth varied inversely with growing-season water deficiency (fig. 7). Without exception, the trees on plots cleared of hardwoods outgrew those on the control plots. Contrary to expectations, growth differences between treatments were not greatest when seasonal water deficiencies were most acute.

In December 1953, 33 months after the Crossett study was established, a severe tornado totally destroyed one treated and one control out of the original six plots. Annual remeasurements were continued on the four surviving plots until 1961 to salvage as much information as possible.

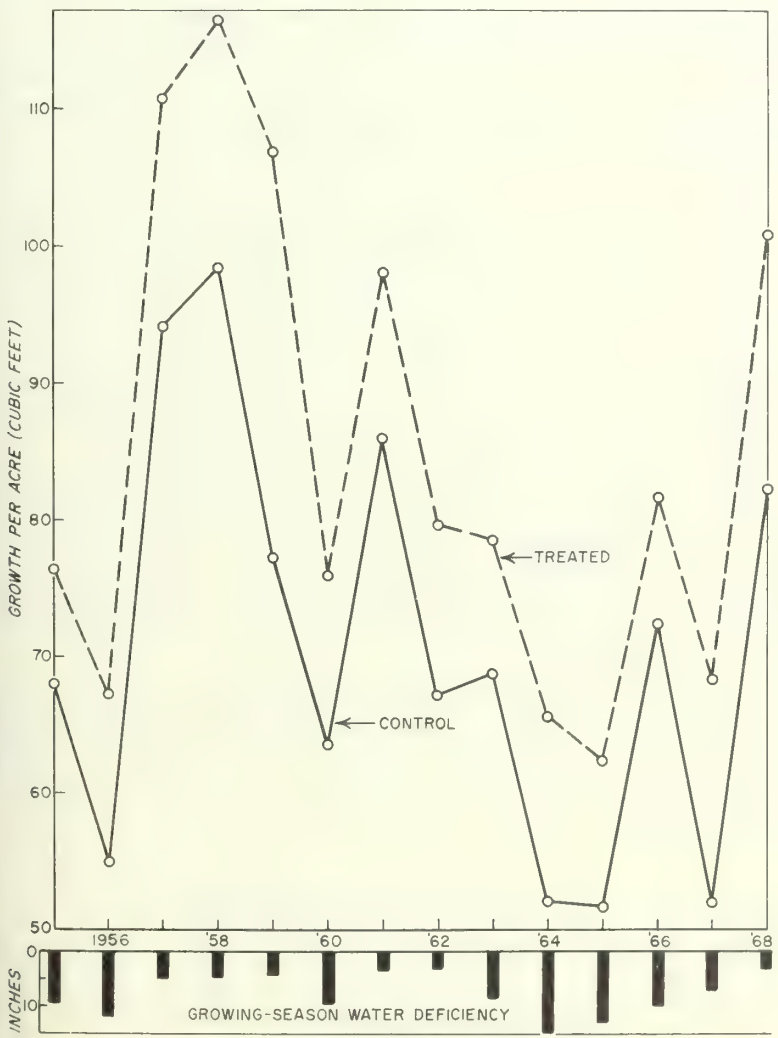


Figure 7.—*Current annual cubic growth per acre.*

Average annual growth on all plots was very high; in 1955 i was 1,293 board feet and 154.8 cubic feet per acre on one plo Treated plots consistently outperformed the controls:

Treatment	Cubic feet[1]	Board feet[2]	Square fee of basal are
Hardwoods removed	108.2	926	3.0
Hardwoods left	75.6	584	2.1
Difference	32.6	342	.9

[1]All trees included.
[2]International ¼-inch rule. Trees 9½ inches d.b.h. and larger.

The periodic annual growth differences for the entire stud were significant at the 5 percent level despite the insensitivit resulting from having only two treatment replications. The tot per-acre growth advantage resulting from understory eradicatio amounted to 359 cubic feet, 3,760 board feet, and 9.9 square fe of basal area.

SUMMARY AND CONCLUSIONS

The two tests show that dense understory hardwoods signif cantly reduce growth of mixed stands of loblolly and shortle pine. Total 14-year growth differences in favor of hardwood-fr plots amounted to 200 cubic feet, or 1,720 board feet per acr In the 11-year-study, gross differences were even more pronounce totaling 359 cubic feet, or 3,760 board feet per acre.

Regardless of moisture conditions during the growing seaso pines on plots divested of understory hardwoods consistently ou grew those on control plots. Contrary to expectation, growth d ferences were not greater when moisture was deficient than und favorable conditions.

From evidence provided by these two studies and other su porting data, it is clear that dense understories of hardwoo materially lessen the average annual growth of even-aged loblol shortleaf pine stands on upland sites. Yields can be meaningful increased by removing these understories.

LITERATURE CITED

1. Bower, D. R., and Ferguson, E. R.
1968. Understory removal improves shortleaf pine growt J. Forest. 66: 421-422.

Klawitter, R. A.
1966. Diameter growth of mature loblolly pine unaffected by under-story control. South. Lumberman 213 (2656) : 154-155.

McClay, T. A.
1955. Loblolly pine growth as affected by removal of understory hardwoods and shrubs. USDA Forest Serv. Res. Note SE-73, 2 pp. Southeast. Forest Exp. Sta., Asheville, N. C.

Russell, T. E.
1961. Control of understory hardwoods fails to speed growth of pole-size loblolly. USDA Forest Serv. South. Forest Exp. Sta. South. Forest. Notes 131.

Zahner, R.
1956. Evaluating summer water deficiencies. USDA Forest Serv. South. Forest Exp. Sta. Occas. Pap. 150, 18 pp.

Zahner, R.
1958. Hardwood understory depletes soil water in pine stands. Forest Sci. 4: 178-184.

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Eradicating Understory Hardwoods By Repeated Prescribed Burning

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1970

Eradicating Understory Hardwoods By Repeated Prescribed Burning

Charles X Grano

In a loblolly-shortleaf pine stand containing abundant litter, one winter fire killed 94 percent of the stems of understory hardwoods up to 3.5 inches in diameter at the base. Prolific sprouting ensued. Eleven annual summer burns eliminated sprouting on 85 percent of the rootstocks, and seven biennial summer burns eliminated sprouting on 59 percent of them.

Some form of hardwood control is necessary for the management of loblolly (*Pinus taeda* L.) and shortleaf (*P. echinata* Mill.) pines on most sites in the South. Since plant succession in these stands is toward a hardwood climax, the hardwoods will dominate unless they are kept in check. Furthermore, the rate of succession in this direction is apparently faster on good than on poor sites (*8*). The hardwoods first appear in pine stands as dense understories that hamper establishment of reproduction and may reduce growth of the overstory (*4*).

Of the various methods of killing the aboveground portions of hardwoods, fire is the most economical. However, the rootstocks of many hardwood species in the South sprout prolifically, making permanent control difficult. To completely eradicate hardwoods, the rootstocks must be killed or prevented from sprouting. Encouraging results were obtained with repeated fires in the Southeast and Atlantic Coastal Plain in the 1950's. Foresters in the Midsouth wanted to know if repeated fires would be equally effective in their area where conditions are highly favorable to hardwood growth, and resprouting is vigorous and persistent. A 3-year study designed to find the answer is described here.

The project was done cooperatively by the USDA Forest Service and the Crossett Division of Georgia-Pacific Corporation.

STUDY AREA

The test was made in a mature even-aged loblolly-shortleaf pine stand growing on Grenada and Calloway silt loams in Ashley County, Arkansas. These are imperfectly drained loess soils underlain by a fragipan at a depth of 18 to 24 inches. A 2-percent north-to-south slope provided good surface drainage. At the beginning of the study the overstory contained about 64 square feet of pine basal area per acre in trees averaging 15 inches d.b.h., and 17 square feet of oaks and gums averaging 8 inches d.b.h. The under-

story was very dense; it contained about 10,000 small hardw plants per acre, whose tallest stems averaged 1.6 inches in diame 6 inches above ground. Southern red oak (*Quercus falcata* Mich sweetgum (*Liquidambar styraciflua* L.), and blackgum (*N sylvatica* Marsh.) were predominant. Elm (*Ulmus americana* sumac (*Rhus* spp.), ash (*Fraxinus* spp.), dogwood (*Cornus flo* L.), hickory (*Carya* spp.), red maple (*Acer rubrum* L.), Ameri holly (*Ilex opaca* Ait.), and hawthorn (*Crataegus* spp.) were pres in lesser numbers.

METHODS

The burning treatments chosen for study were those that l proven most successful in other areas. Most earlier investigat concluded that repeated summer fires provide greater and long lasting sprout control than repeated winter burns (*1, 2, 3,* However, a heavy accumulation of ground fuel makes initial su mer burns in pine stands hazardous. Thus, it was decided to h a winter fire initially to minimize the risk, and summer fires the after.

Ferguson's experiences in a pine-hardwood stand in Te indicated that headfires kill more of the original hardwood ste than backfires (*3*). Headfires were therefore used in the pres study.

Two treatments were tested. The first burn in each was m in the winter of 1954-55. In one treatment the plots were bur again in the summer of 1956 and each summer thereafter, exc in 1958 when burning conditions were unfavorable. In the sec treatment a burn was made in the summer of 1957 and ev second summer thereafter. The two treatments were replica four times in a randomized block design.

Study plots were too small, 0.1 acre, to confine the fires individual plots. To measure the effect with momentum well est lished, fires were set well outside the plot boundaries and p mitted to burn into the plots. The eight study plots were loca inside a 15-acre area. In the initial burn, the entire area was fir This procedure was followed whenever the schedule required annual and biennial plots to be burned on the same date. Wh the annual plots alone were to be fired, the biennial plots w isolated by a fireline.

Litter samples for each plot were obtained prior to each b to determine the pounds per acre, ovendry weight, of ground fu After the initial burn the fuel supplies represented 1 and 2 ye accumulation for the annual and biennial burns. Final burns both treatments were made in 1967. Thus, 12 annual and se biennial burns were made.

Fire severity was visually classed as:

Light. Fire sluggish and discontinuous, leaving unburned atches. Surface litter consumed but lower layers largely intact. eaves of hardwood understory scorched, and base of stems lightly narred.

Medium. Momentum of fire well sustained; clean, even urn of litter over the entire area. Some green hardwood leaves con-umed and the remainder completely scorched. Decided charring f hardwood stems.

Intense. Clean, hot burn over the entire area. Litter, in-uding lowest layer, completely consumed. The leaves and the em and branch ends of most small hardwoods ignited. Small ardwood stems deeply charred or destroyed.

All burns were made with the wind. For safety, fire was set n the flanks slightly in advance of the head. When possible, the ummer burns were made on days when the relative humidity was 5 percent or less and a steady wind of 2 to 5 miles per hour was owing. Ambient temperatures during the summer burns usually ere between 85 and 100° F. Relative humidity in excess of 45 ercent or little air movement resulted in inefficient, discontinuous urns, especially where ground fuel was light.

On each plot, 60 sample hardwood plants were pinned, gged, and numbered for repeated examination throughout the udy. The identity of each plant was maintained in all inventories. hree species groups were recognized: oak, gum (sweetgum and blackgum), and others (elm, maple, hickory, dogwood, sumac, persimmon, hawthorn, holly, and ash). Stems were placed in one f four diameter classes: 0.5 inch or less, 0.6 to 1.5, 1.6 to 2.5, nd 2.6 to 3.5 inches. All diameters were measured 6 inches above ground. If the plant consisted of several stems, only the tallest one as measured. On each study plot, five hardwood plants in each f the 12 species-diameter categories were represented. Plants were examined prior to each burn to determine number and condition f the original stems, number of sprouts, and diameter of the individual stem or the dominant sprout in a clump. Final examina-tions were made in 1968, 1 year after the last burn.

RESULTS

Prior to the first burn the dense hardwood understory had ontributed materially to the 11,332 pounds of litter per acre hich had accumulated on the plots. After a few burns the con-tributions from this source was negligible, particularly on the nnually burned plots. Needle litter became the principal fuel. After the sharp reductions resulting from the 1955, 1956, and

1957 burns, the fuel mass tended to stabilize at about 4,600 pound per acre. Because of their 2-year accumulation period, the biennia plots generally had a greater fuel supply per burn than the plo burned annually. Table 1 shows the severity of individual burn and the amount of fuel available for each.

Table 1.—*Burning record*

Year	Litter		Temperature	Relative humidity	Wind	Fuel moisture	Fire intensity	
	Annually burned plots	Biennially burned plots					Annually burned plots	Biennially burned plots
	Lbs. per acre[1]		*°F.*	*Percent*	*M.p.h.*	*Percent*		
1955	11,450	11,240	78	60	3-15	7	Medium	Mediu
1956	7,320	. . .	96	58	1-2	7	Light	. .
1957	5,760	8,160	96	34	3	6	Severe	Severe
1958	([2])							
1959	4,850	3,550	86	52	1-2	6	Light	Light
1960	4,750	. . .	85	50	3	6	Very light	. .
1961	4,830	4,780	75	20	1-2	5	Light	Mediu
1962	4,600	. . .	96	45	2	5	Medium	. .
1963	4,590	6,170	87	40	7	7	Severe	Sever
1964	3,600	. . .	94	48	4	9	Medium	. .
1965	4,240	5,240	98	40	2	10	Medium	Mediu
1966	3,860	. . .	94	40	3-5	9	Severe	. .
1967	4,040	4,880	92	45	3	15	Medium	Mediu

[1]Ovendry weight.
[2]No burn made.

An abundance of fuel and favorable weather generated a very effective initial burn. The fire killed the original stems o 91.6 percent of the hardwood plants on the annually burned plo and 96.7 percent on the biennially burned plots. In the final inve tory in 1968 only 1.2 percent of the original stems on annual burned plots and 1.7 percent on biennially burned plots still su vived. These few were invariably the largest stems.

Although mortality of original stems was similar for the tw treatments, sprouting differed significantly[1] by burning interv (fig. 1). In 1968, 85.0 percent of the plants that had been to killed on annually burned plots were free of sprouts. On biennial burned plots, 59.2 percent of such plants were not sprouting. The plants were presumed to be dead.

If a given degree of hardwood control is desired in the short possible time, the results show that annual burns are superi To determine whether the greater fuel accumulations for t individual biennial burns made them more effective than indivi ual annual burns, results of the first seven annual fires were co

[1]Only the 5-percent level of significance is reported in this paper.

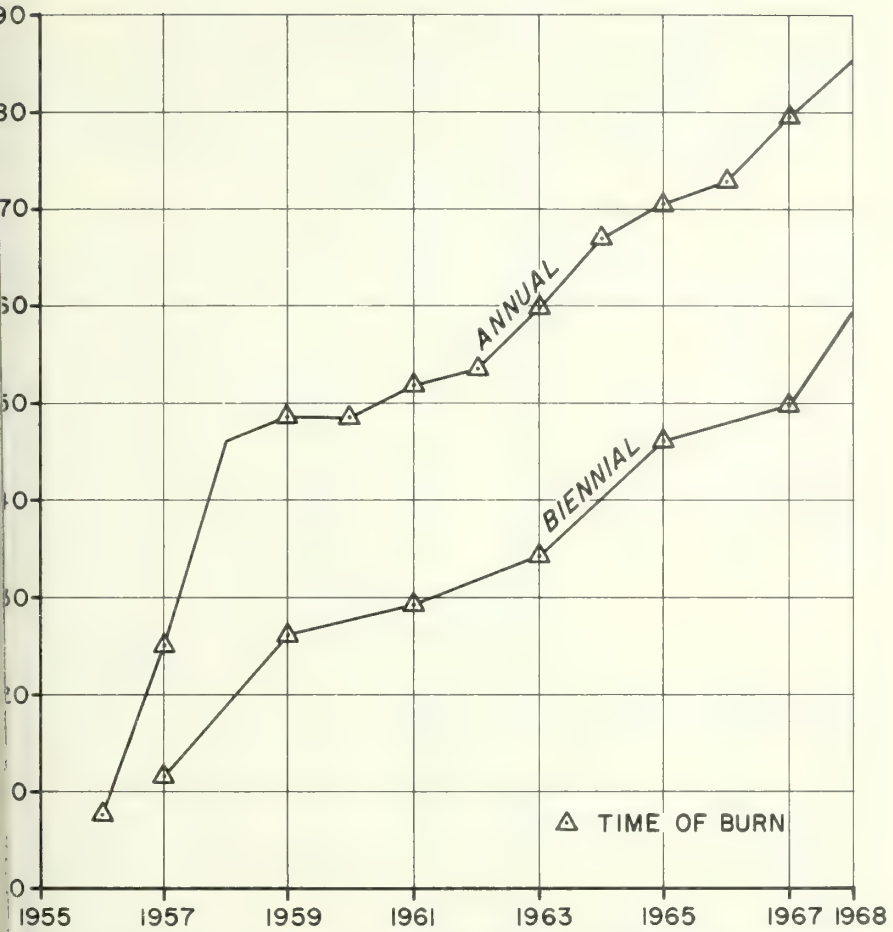

Figure 1.—*Percent of original stems of all species killed by annual and biennial burns and not sprouting. Inventories were taken prior to each burn.*

pared with those of the seven biennial fires. In five of the seven cases, fires spaced 1 and 2 years apart were equally effective in controlling sprouting. The total control after seven burns was almost identical—59.6 percent killed and not sprouting for annual burns versus 59.2 percent for biennial burns.

Regardless of plant size, sprouting occurred on almost all of the original plants whose tops were consumed by the first burn (Table 2). The number of plants sprouting diminished with succeeding burns. On annually burned plots, small plants may have had a slightly greater tendency to resprout than large plants, but this trait was neither pronounced nor consistent. After 12 burns, sprouting of stems 1.6 to 2.5 inches in diameter was significantly less than that of smaller stems, but it was also less than that of larger stems. On the biennially burned plots, there were no significant differences in resprouting capacity due to original stem

Table 2.—*Fire effects on hardwoods in relation to stem size*

Number of burns	Original diameter class[1]							
	0.0-0.5 inch		0.6-1.5 inches		1.6-2.5 inches		2.6-3.5 inches	
	Top-killed	Killed[2] and not sprouting	Top-killed	Killed[2] and not sprouting	Top-killed	Killed[2] and not sprouting	Top-killed	Kille and r sprou
	Percent							
ANNUAL BURNS								
1	100.0	8.3	100.0	5.0	95.0	6.7	70.0	
2	100.0	26.7	100.0	13.3	96.7	25.0	78.3	3
3	100.0	41.7	100.0	31.7	98.3	51.7	90.0	5
[3]3	100.0	41.7	100.0	35.0	98.3	58.3	93.3	5
4	100.0	35.0	100.0	36.7	100.0	61.7	93.3	6
5	100.0	38.3	100.0	40.0	100.0	65.0	95.0	6
6	100.0	41.7	100.0	41.7	100.0	65.0	95.0	6
7	100.0	50.0	100.0	48.3	100.0	70.0	95.0	7
8	100.0	58.3	100.0	53.3	100.0	80.0	95.0	7
9	100.0	63.3	100.0	60.0	100.0	81.7	95.0	7
10	100.0	61.7	100.0	66.7	100.0	83.3	95.0	7
11	100.0	68.3	100.0	73.3	100.0	93.3	95.0	8
12	100.0	76.6	100.0	86.7	100.0	95.0	95.0	8
BIENNIAL BURNS								
1	100.0	15.0	100.0	3.3	96.7	10.0	90.0	1
2	100.0	30.0	100.0	21.7	98.3	20.0	91.7	3
3	100.0	31.7	100.0	25.0	98.3	20.0	93.3	4
4	100.0	30.0	100.0	33.3	98.3	31.7	93.3	4
5	100.0	45.0	100.0	45.0	98.3	41.7	93.3	5
6	100.0	45.0	100.0	51.7	98.3	41.7	95.0	6
7	100.0	61.7	100.0	61.7	98.3	51.7	95.0	6

[1]Diameter of dominant stems measured 6 inches from ground.
[2]Expressed as a percentage of top-killed trees.
[3]No burn made in 1958 but hardwood was inventoried.

diameter. Inasmuch as all the hardwoods involved in this stu were 3.5 inches at the base or less, the similarity in sprout response among size classes is not surprising.

Annual burns were equally effective on all three spec groups. Biennial burns controlled sprouting of oaks significan better than that of gums and other species. By the end of t study, the seven biennial burns had resulted in just about t same degree of sprout control on oaks as did the 12 annual bu (table 3). However, the annual burns were far more effect than the biennial burns in preventing sprouting of gums and ot species.

Prior to the first burn there were 344 stems on the 240 sam plants on the annually burned plots (fig. 2). One year later number had increased to 1,383. After this a continuous decl ensued; 147 stems were present in 1968. Similar but slower tre were observed on the biennially burned plots. Here the origi

Table 3.—*Fire effects on small hardwoods, by species groups*

Number of burns	Oak		Gum		Others	
	Top-killed	Killed[1] and not sprouting	Top-killed	Killed[1] and not sprouting	Top-killed	Killed[1] and not sprouting
	Percent					
	ANNUAL BURNS					
1	91.2	6.2	97.5	10.0	85.0	6.2
2	92.6	21.2	98.8	25.0	90.8	27.5
3	97.5	43.8	100.0	46.2	93.8	47.5
[2]3	98.8	43.8	100.0	47.5	95.0	53.8
4	98.8	45.0	100.0	48.8	96.3	51.2
5	98.8	48.8	100.0	52.5	97.6	53.8
6	98.8	53.8	100.0	50.0	97.6	52.5
7	98.8	55.0	100.0	63.8	97.6	61.2
8	98.8	60.0	100.0	76.2	97.6	65.0
9	98.8	62.5	100.0	77.5	97.6	73.8
10	98.8	63.8	100.0	81.2	97.6	72.5
11	98.8	71.2	100.0	88.8	97.6	82.5
12	98.8	75.0	100.0	95.0	97.6	85.0
	BIENNIAL BURNS					
1	95.0	6.2	100.0	13.8	95.0	15.0
2	95.0	22.5	100.0	26.2	97.5	31.2
3	95.0	32.5	100.0	27.5	98.8	27.5
4	95.0	43.8	100.0	27.5	98.8	35.0
5	95.0	62.5	100.0	37.5	98.8	40.0
6	96.2	65.0	100.0	41.2	98.8	42.5
7	96.2	72.5	100.0	56.2	98.8	48.8

[1] Expressed as a percentage of top-killed trees only.
[2] No burn made in 1958 but hardwood was inventoried.

335 stems increased to 960 in the 2 years after the first burn, although the sprouting 1 year after the burn was probably similar to that on the annually burned plots. By 1968 sprout numbers had declined to 660.

Distribution of sprouts among sample plants within plots was not uniform. Often an individual plant within a species group proved to be an unusually prolific sprouter. On the average annually burned plot, one oak plant accounted for 33 percent of the oak sprouts found at the end of the study. Likewise, one gum accounted for 56 percent of the gum sprouts and one plant accounted for 62 percent of the sprouts of other species on the average plot. A similar situation prevailed on the biennialy burned plots.

Stem numbers increased sharply as a result of burning, but the average diameter of the bases of dominant stems dropped steadily with each burn from a high of 1.6 inches to a low of 0.1 inch (fig. 2). Proportionately, the biggest diameter decrease followed

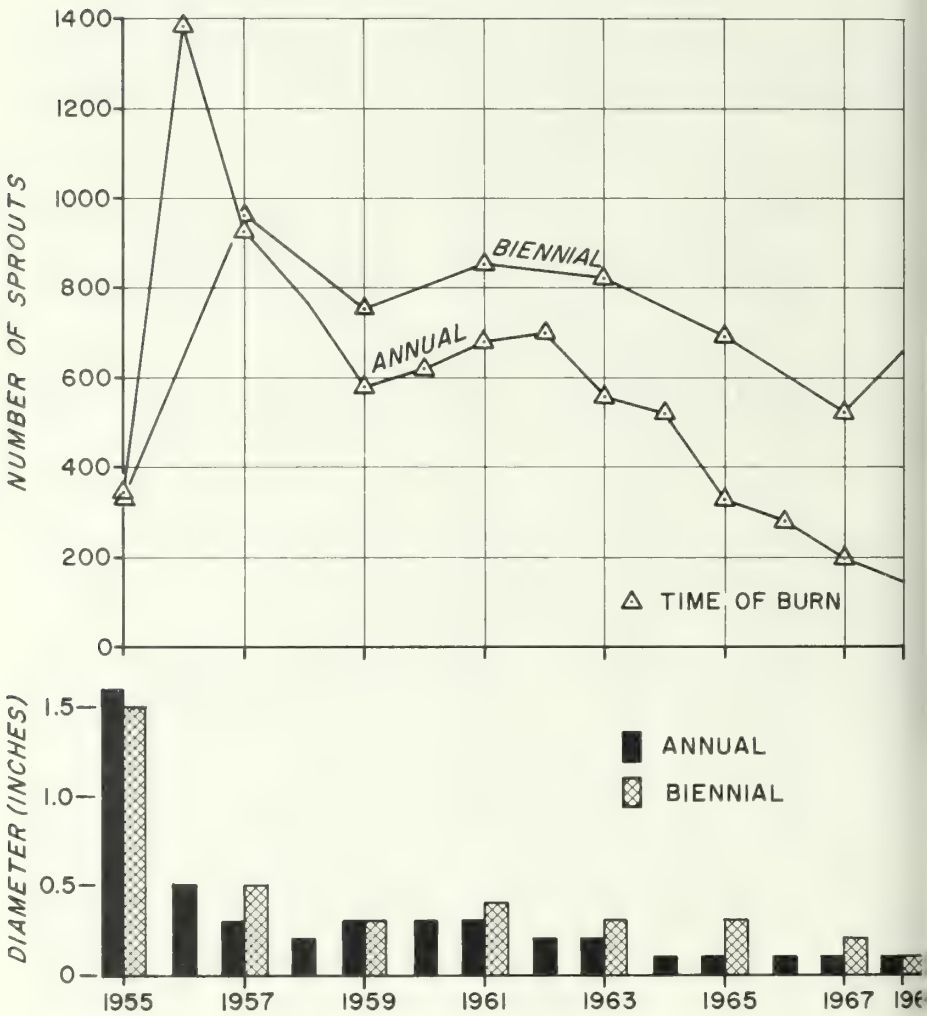

Figure 2.—*Effects of annual and biennial burns on sprouting (above) and diameter of dominant stems (below) on 240 sample plants. Diameters were measured 6 inches above ground and inventories were taken prior to each burn.*

the first fire. A reduction in average diameter to 0.1 inch was achieved in 8 years with annual burns and 13 years with biennial burns. However, the number of fires required was about the same—eight annual and seven biennial burns. Because of the drastic decrease in stem size, a spectacular reduction in vegetative cover took place, particularly on the annually burned plots (fig. 3).

CONCLUSIONS

The results presented here and those of other studies show that when ample fuel is available a winter burn will destroy the

Figure 3.—*The understory after nine annual burns.*

aboveground portion of almost all hardwoods up to 3.5 inches in diameter at the base. Repeated summer burns at 1- or 2-year intervals can reduce sprouting to any desired degree, even under conditions highly conducive to sprouting. For practical purposes, equal numbers of annual or biennial burns will afford the same levels of sprout control, but annual burns achieve the results faster.

Despite fire's proven ability to control hardwoods, many land managers are reluctant to burn. Some fear that repeated prescribed burning will be expensive. Others fear deterioration of soil quality, damage to the overstory, and loss in growth. If the work is done properly, these fears are unjustified. In loblolly pine stands on the Virginia Coastal Plain, Trousdell and Langdon made an initial winter burn and three consecutive summer burns for about one-fourth the cost of disking (7). In the vicinity of the present study, industry has made initial burns at a cost of 50 cents per acre and subsequent burns for 40 cents per burn per acre. The danger to soil or stand is minimal if fires are correctly made.

One winter and eight annual summer burns had little effect on the nutrient content and structure of the surface 4 inches of loess soil on flat forested terrain in southern Arkansas (*6*). On the basis of their own experience and a comprehensive review of the literature, Wenger and Trousdell concluded that neither winter nor summer prescribed burns adversely affect the growth of loblolly pine overstories (*9*). The 13-year test reported here supports their conclusion, for there were no losses in the pine overstory that could be attributed to fire.

LITERATURE CITED

1. Brender, E. V., and Copper, R. W.
   1968. Prescribed burning in Georgia's Piedmont loblolly pine stands. J. Forest. 66: 31-36.

2. Chaiken, L. E.
   1952. Annual summer fires kill hardwood root stocks. USDA Forest Serv. Southeast. Forest Exp. Sta. Res. Notes 19, 1 p.

3. Ferguson, E. R.
   1957. Stem-kill and sprouting following prescribed fires in a pine-hardwood stand in Texas. J. Forest. 55: 426-429.

4. Grano, C. X.
   1970. Small hardwoods reduce growth of pine overstory. USDA Forest Serv. Res. Pap. SO-55, 9 pp. South Forest Exp. Sta., New Orleans, La.

5. Lotti, T., Klawitter, R. A., and LeGrande, W. P.
   1960. Prescribed burning for understory control in loblolly pine stands of the Coastal Plain. USDA Forest Serv. Southeast. Forest Exp. Sta., Sta. Pap. 116, 19 pp.

6. Moehring, D. M., Grano, C. X, and Bassett, J. R.
   1966. Properties of forested loess soils after repeated prescribed burns. USDA Forest Serv. Res. Note SO-40 4 pp. South. Forest Exp. Sta., New Orleans, La.

7. Trousdell, K. B., and Langdon, O. G.
   1967. Disking and prescribed burning for loblolly pine regeneration. J. Forest. 65: 548-551.

Wenger, K. F.
1969. Silvics and ecology of loblolly-shortleaf pine-hardwood forests. *In* The ecology of southern forests, pp. 91-98. La. State Univ. 17th Annu. Forest. Symp. Proc. 1968. La. State Univ. Press.

Wenger, K. F., and Trousdell, K. B.
1958. Natural regeneration of loblolly pine in the South Atlantic Coastal Plain. USDA Prod. Res. Rep. 13, 78 pp.

Direct-Seeding Longleaf Pine

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Acknowledgment

This tribute is to foresters who pioneered in direct seeding before repellents had been developed, and whose contributions are too important to be forgotten. They cooperated unstintingly with the researchers, and their repeated pilot trials, conducted despite numerous failures, afforded the necessary opportunities to test ideas and observe results on a practical scale. Equally important, their confidence and encouragement did much to keep the research active when progress was slow. The persons and organizations named here deserve special recognition:

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1970

Direct-Seeding Longleaf Pine

W. F. Mann, Jr.

Southern Forest Experiment Station
Forest Service
U.S. Department of Agriculture

Longleaf pine seedling just before seadcoat is shed. This species is challenging to manage, and rewarding to grow.

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Birds were major seed predators before a repellent was developed.

This publication updates "Guidelines for direct-seeding longleaf pine," which was issued in 1959 as Occasional Paper 171 of the Southern Forest Experiment Station. Prescriptions for longleaf have been improved substantially since then. New techniques have resulted from additional research coupled with experience from practical operations. More than 200,000 acres have been sown on a wide array of sites across the South. These operations—many of which have been observed by the author—not only served as proving grounds for new developments, but established that the recommendations are broadly applicable throughout the native range of longleaf pine.

Research to develop reliable methods for direct-seeding longleaf was initiated by scientists of the Southern Forest Experiment Station in 1947. For 8 years, studies were conducted to determine seedbed requirements on various soils, optimum season of sowing, predators of seed and seedlings, and methods of distributing seed. Concurrently, research was concentrated on finding a coating to protect seeds from birds, rodents, and insects.

A bird repellent was discovered in 1954, and was followed in 1957 by a combination repellent effective against most of the major predators. Longleaf was the first of the southern pines to be sown operationally—beginning about 1955. Seeding has become the most prevalent method of regenerating this species, because planting nursery-grown seedlings is expensive and survival is often low.

The purpose of this paper is to cover all phases of a direct-seeding operation from initial planning to appraisal of results. Each major aspect is covered in a separate section, and with sufficient detail to guide a forester with no previous experience through his first operation. Recommendations for additional reading are listed at the end of the text.

Guidelines given here should not be applied to other species, which differ with respect to site preparation, season of sowing, seed treatments, and sowing rates. Similar papers for loblolly and slash pines were published separately in 1961 and 1964; the one for loblolly was updated in 1966 (Mann and Derr, 1964, 1966). Information on other species is also available (Mann 1966).

ADVANCE PLANNING

Site Appraisal

Sites to be regenerated should be inspected to determine if direct-seeding is practical on them and whether longleaf is a suitable species. Such inspections should be made 8 to 12 months in advance of the intended sowing date.

Longleaf is well adapted to a wide variety of soils in the Atlantic and Gulf Coastal Plains, and in the Appalachian foothills in Alabama and Georgia. Loblolly and slash pines also grow rapidly on many of the soils that are productive for longleaf. The choice of species on such sites will depend on the preference of the landowner.

Longleaf has several characteristics that must be considered carefully before it is selected over other species. Foremost is slow initiation of height growth, which is often delayed until the fourth or fifth year. This stemless period reduces growth and yields, and defers the time when returns can be obtained by thinning. Young longleaf are often attacked by the brown-spot needle blight, which retards growth and kills pines if left unchecked. Periodic prescribed burning is needed to control the disease until pines reach a height of about 3 feet, when they are no longer subject to severe infection. The incidence of infection varies from site to site, but usually several burns are necessary, and add to the expense of management. Occasionally pines escape infection and burning is unnecessary.

While longleaf is difficult to manage in early years, it is often selected for sites where the hazard from wildfire is high. Seedlings, even those only a year old, are highly resistant to damage by fire. Other advantages are freedom from disease and insects after juvenile years, and the high proportion of poles and piling obtained from well-stocked stands. Whatever the reason for selection, it is usually safe to regenerate longleaf on sites it occupied in virgin stands.

Some sites that originally had stands of longleaf are in the flatwoods region. Here hardpans and slowly permeable subsoils impede movement of water through the soil profile, resulting in excessive surface water during wet seasons. In dry weather, the sites can be as droughty as

sandy ridgetops, because moisture in the shallow horizon above the hardpan is quickly depleted. These soils may be difficult to regenerate by any method, and planting may be surer than seeding. In an extreme drought during the first year the entire seeding may be lost. At the other extreme, long inundation will cause serious loss of seed viability, though brief submergence may do no harm. While direct seeding on flatwoods sites has been moderately successful, the extra risks should be recognized.

Many former longleaf sites are dominated by scrub hardwoods. There are two common methods of destroying this competing overstory. First is complete removal by bulldozing, chopping, disking, or chaining in advance of sowing. The technique selected should minimize sprouting, because slow-growing longleaf seedlings are quickly overtopped. The other method is to kill the hardwood overstory by tree injection in the first summer after sowing. Prompt release is necessary for maximum survival and growth.

Landowners are often tempted to try direct seeding where planting has been unsuccessful. Such sites should be avoided, especially in initial operations. The better course is to conduct early trials on average or good sites and tackle more difficult ones after experience is gain There are few exceptions to this general r The most notable example is spoil banks from strip mining, where steep, rocky slo almost preclude planting. Such sites have b seeded with remarkable success in north Alabama.

Several situations should be avoided in ad tion to those where seeds are apt to be s merged. First are steep, eroded sites where se are easily washed away. Longleaf seeds, e when coated with repellents, are readily mo by water. The other situation to avoid is bro casting on coarse, sandy topsoils. These s dry out within a few hours after a rain, and satisfactory germination, seeds must be bu about ¼ to ½ inch deep. A row-seeding machi which in a single pass drops and covers the s in a strip prepared by scalping or furrowing suitable for large tracts. On small tracts, se can be sown on spots and a hoe or firerake u to cover them with soil.

Once the decision has been made to dir seed longleaf, it is necessary to consider me of protecting seed and seedlings.

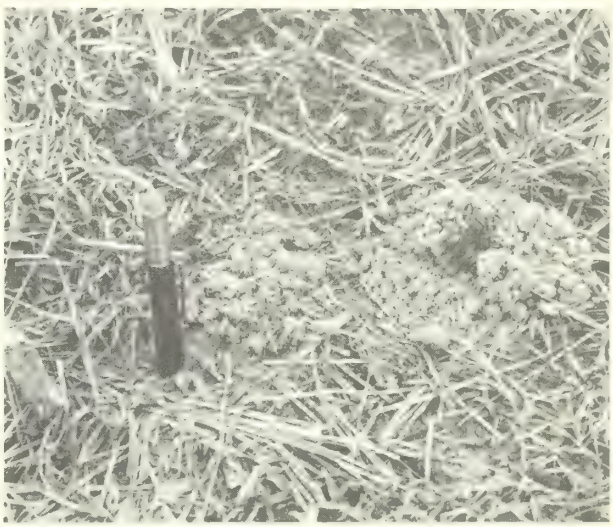
Longleaf has been seeded successfully on steep, rocky spoil banks that are virtually impossible to plant.

Seed sown on the surface of deep, dry sand germinates poorly.

otection

The repellent coating wards off most of the jor predators but is ineffective against such ers as town ants, short-tailed crickets, and uirrels, which may be numerous on localized eas. The hazards from predators that are not fluenced by the repellent seed coating should estimated when the site is appraised initially. Town ants, found in portions of east Texas d Louisiana, destroy seed as well as seedgs. Consequently, colonies must be located d treated with mirex bait in advance of sowing chols 1966). Since this insect can defoliate en sapling-sized trees, areas should be reecked annually for new infestations until the nes are at least 10 feet tall.

Short-tailed crickets carry seed to their burws and destroy young seedlings in winter and rly spring. They may be serious predators on variety of sites but seem to prefer wet, heavy ils, where as many as 10,000 burrows per acre ve been found. Damage declines sharply with e advent of warmer weather, which favors the growth of grasses and weeds. The repellent ating does not keep the crickets from carrying ay seed, but it usually kills them after a period time. As many as seven treated seeds have en found in a single burrow with a dead cricket, dicating that substantial damage may be infted before the insecticide in the coating is fective. Many heavily infested areas have rvertheless been sown successfully. Present



Burrows of the short-tailed cricket are indicated by small mounds of subsoil.

recommendations are to maintain high sowing rates where cricket burrows number 1,000 or more per acre.

Squirrels may eat considerable seed, especially in stands of hardwoods. Spot and furrow sowings seem especially vulnerable, probably because the seeds are easy to find. Laboratory trials clearly show that squirrels are not repelled or harmed by the repellent coating. The best protection devised so far is to reduce the population by hunting before sowing is started. Permission from local game authorities will be needed for shooting out of season. Killing hardwoods before seeding should alter the habitat and cause squir-

rels to leave the area. Another method of reducing losses is to sow as hardwood leaves are falling, so that seeds will be covered and hard to find. The usual procedure is to wait until 50 to 75 percent of the leaves are down, and then burn and sow. The remaining leaf drop will be enough to cover the seed without smothering the new seedlings.

Rabbits eat both seed and seedlings. The repellent coating ordinarily protects the seed fairly well, but cotyledon-stage seedlings are susceptible to heavy damage. The succulent seedlings are nipped off close to the groundline, with only a short stub to indicate that damage has taken place. Losses are greatest in the winter when other green vegetation is scarce, but they also occur in the spring. Assistance of State wildlife officials should be sought when populations are high enough to be a problem.

Rabbits clip off newly germinated seedlings near the groundline, often causing substantial losses.

Pocket gophers, often called salamanders, kill seedlings by eating the roots. Pines are seldom, if ever, damaged during their first year, but after that they are vulnerable until about 10 feet tall. Small trees may disappear completely as the gophers pull them into tunnels to feed on roots or consume them entirely. Larger ones turn brown and often lean over before the presence of gophers is recognized. They are easily uprooted by hand, as only short stubs of roots remain. Gophers prefer sandy, well-drained soils, where they may cause serious losses over areas of several hundred acres. Their presence is indicated by mounds of soil about 8 inches high a 12 inches in diameter; the mounds are connect by tunnels a few inches below the soil surfac Grass may conceal the mounds, and the best tir to check for them is after a burn for seedb preparation or brown-spot control. Gophers shou be controlled as soon as they are detected. A effective method is to place a handful of mi maize treated with strychnine in the tunnels 1-chain intervals within the infested area (Wak ley 1954).

Grazing by hogs, cattle, and sheep has caus the failure of a number of longleaf seedin Hogs, which uproot trees as large as 10 feet ta must be excluded completely before an area sown. Cattle and sheep should be eliminat during the first year, because they kill you seedlings by trampling or by eating the needl along with grass. After the first year, lig grazing by cattle, and perhaps sheep, can tolerated. Forage utilization should not exce 50 percent, and precautions should be taken prevent concentrated grazing on small areas.

Seedbed preparation, hardwood control, a prescribed burning will attract livestock fro several miles away. Consequently, areas p viously grazed lightly may suddenly be overru especially small tracts where relatively few a mals can result in overuse. It is necessary, the to appraise the number of animals using near land, as well as those on the area to be rege erated.

Control of livestock under open range con tions may be difficult. Burning more acre than will be sown, or burning nearby areas a diversionary measure, often reduces the haz from cattle and sheep. Temporary fencing, w untreated posts and several strands of barb wire, suffices to exclude cattle for a few yea Where hogs are a problem, fences must be c structed with net and barbed wire, and w treated posts that will last at least 10 yea To keep per-acre costs of all types of fen down, large areas must be enclosed.

SEEDBED PREPARATION

The type of seedbed to prepare depends soil, cover conditions, climatic factors, livest hazards, and the value placed on fast ini growth. The method of sowing also should considered, because in some situations it n

e desirable to prepare a seedbed and distribute ed in one operation. In this section, only pre-wing bed treatments are discussed.

Open grassy areas have been sown most often. ney require burning if the rough is heavy; herwise the seeds, which are large and have wing stub attached, are likely to lodge in the ass and fail to germinate. A light rough that sults from burning a year in advance is usu-ly preferable to a fresh burn, as it provides better environment for germination. The light growth of grass accumulates dew and shields ne seed from drying by wind and sun. In years ith ample precipitation, seedling catch may be od on a fresh burn. But a light rough is su-erior when rainfall is scarce during the ger-ination period.

There are some sites where moisture during ne germination period is rarely a problem. On ese, freshly burned seedbeds may have several ajor advantages. Autumn fires, as compared ith earlier burns, result in slower buildup of own spot, slightly faster height growth of seed-ngs, fewer rodents and rabbits, and later con-ol of hardwood sprouts. Sowing on a fresh burn sometimes necessary when seed unexpectedly ecomes available or bad weather prevents spring urning. In these situations the fresh burn is better choice than a heavy rough, except on lling sites where rains may wash seed away.

On dry sites, disking improves first-year sur-val by reducing grasses that compete for soil oisture. It should be done in the summer or rly fall, because the best kill of grasses is ob-ined when the weather is hot and dry. Burning off the grass facilitates pulverization of the soil; the burn can be made immediately before disking or during the preceding winter. A heavy-duty offset disk, cutting about a 7½-foot swath, does a good job at a reasonable cost. It can be pulled by a crawler tractor used in fire suppression. To reduce costs, strips are disked about 8 feet apart. About 20 acres can be strip-disked daily for $3.00 per acre. If seed is confined to the prepared strips part of this cost will be offset by a lower sowing rate.

A limited acreage has been sown with longleaf on sites so wet that elevated, disked beds were required. A bedding harrow with six to eight 28-inch disks, pulled by a heavy crawler tractor, will mound the soil about 6 inches high. Production averages about 20 acres daily at a cost of $4.50 to $5.00 per acre.

To minimize seed losses from silting, disked beds should be allowed to settle for a few months before being sown.

Two factors should be weighed carefully when deciding whether or not to disk. First, germination may be impaired on sites where the surface layers of disked soil dry out fast. Second, intensity of brown-spot infection will be increased. Brown spot is spread largely by rain splatter, and grasses help shield the pine foliage from spores. Consequently the potential gain in growth by reducing competition may be offset by a higher incidence of disease.

Seedbed preparation on sites with a stand of hardwoods is usually coordinated with control of the overstory. If hardwoods are destroyed by heavy machines, burning is often sufficient

Typical cutover site, with a light grass cover suitable for longleaf seeding.

Hardwoods are often destroyed with heavy machines, like this 5-ton disk.

unless disking is required to check sprouting. Burning off the accumulation of leaves is normally necessary when sowing beneath hardwoods. Mechanical preparation is not needed, for grass is sparse under a hardwood canopy.

Plowed furrows have proved unsatisfactory on most sites even though they control competing grasses better than disking does. Their main disadvantages are that seed is washed away on sloping ground or submerged on flat, poo drained sites; erosion is often severe; and sufficient grass develops to carry a suitable f for brown-spot control when the seedlings 2 or 3 years old. Furrowing has been effect in several small operations on flat, well-drain sandy sites where flooding and washing w minor problems. Furrow seeding, a different te nique than sowing in plowed furrows, will discussed in the section on methods of sowi

Dense stand of hardwoods with litter burned to expose mineral soil. Overstory must be deadened early in the first year after sowing.
(Photo by Louisiana Forestry Commission)

SEED PROCUREMENT

As soon as the area for seeding has been inspected, it is time to make detailed arrangements for seed procurement. It is important to plan early, because supplies are sometimes limited and alternative methods must be appraised. A landowner has several choices: he may collect and extract his own seed, collect cones and have the seed extracted by a commercial dealer, or buy cleaned seed. All three have merit, and the landowner's decision will depend on the supply of cones in his area, facilities available to him for processing cones, and cost of commercial seed.

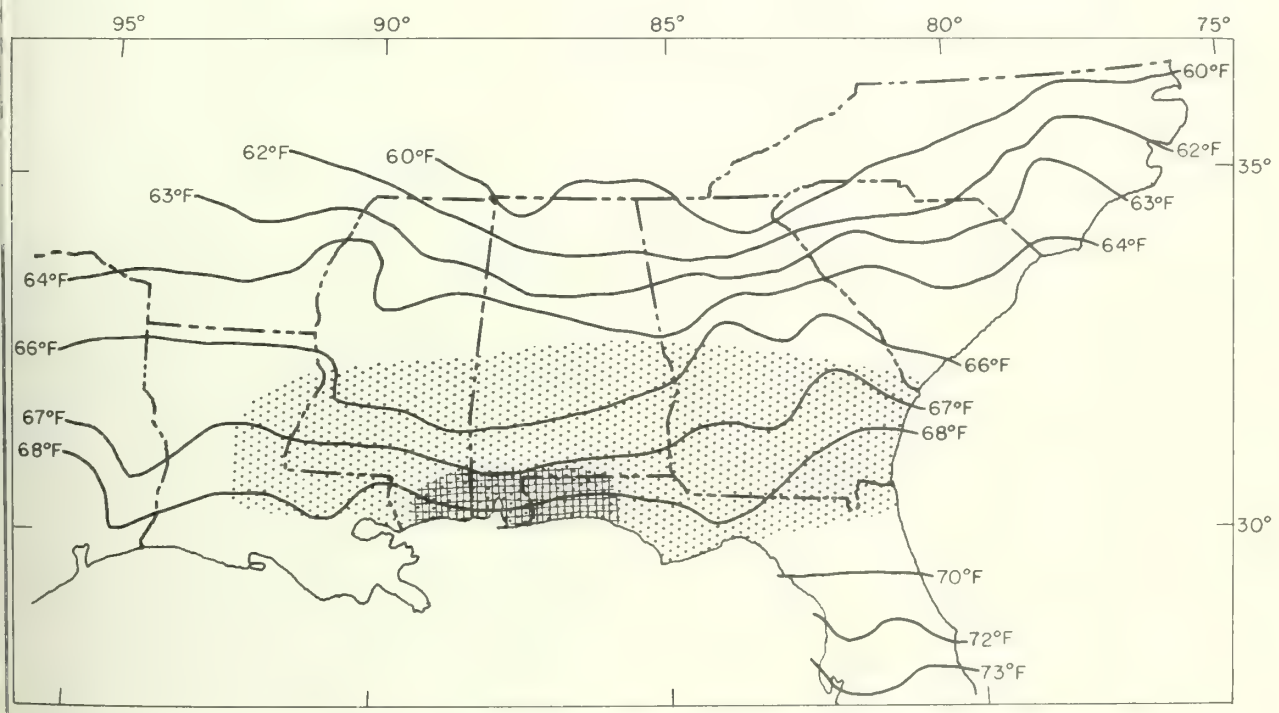
Purchasing from a dealer is the usual method of obtaining seed. It avoids the uncertainties of cost and seed viability, and it is the easiest of the various alternatives. Prices have ranged from $1.75 to $3.00 per pound in recent years, depending on the abundance of seed, the quantity purchased, and how long it was held in storage.

There are two important disadvantages to buying seed. First, the supplier can seldom give assurance that the seed is from trees with above-average form and growth rate, for he gets many of his cones from individuals who are apt to collect from limby trees that are easy to climb. Second, it is often difficult to obtain seed from the zone that will give the best growth and yield in a particular area. For the major portion of the longleaf belt adjacent to the Gulf Coast, the optimum seed-collection zone (Wells 1969) is southeast Mississippi, southern Alabama, and northwest Florida (see map).

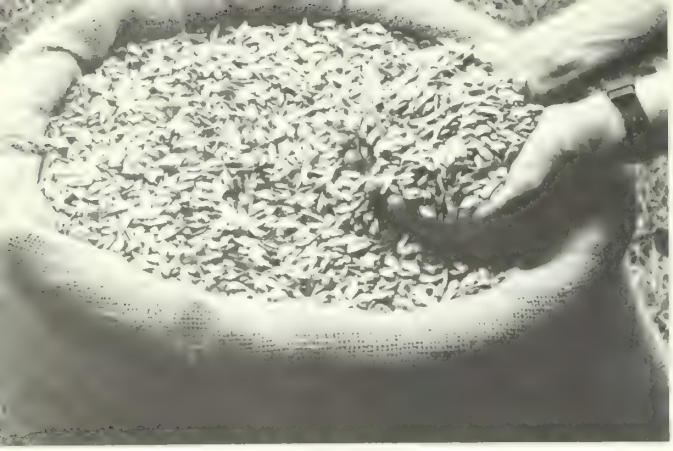
Minimum standards for viability, soundness, purity, and moisture content should be specified when seed is purchased. They should be verified by current tests in the USDA Forest Service's Eastern Tree Seed Laboratory (P. O. Box 1077, Macon, Georgia). The buyer should also know the geographic source of the seed and the year of collection.

Lots should be cleaned to at least 95 percent sound seed by number, a standard easy to attain with modern equipment. Excessive empties waste repellent. Impurities, which clog machines and cause poor distribution, should not exceed 2 percent by weight. A moisture content of 10 percent or less is advisable to insure a reasonable number of seeds per pound and to avoid the task of drying if the lot is to be stored.

For direct seeding, it is preferable to have at least 80 percent viability on a sound-seed basis. Lower viability may be accompanied by a drop



Optimum longleaf pine seed-collection area (hatched) for plantings to be made within stippled area. Isotherms of average annual temperature are shown.



Before seed is coated it should be cleaned of trash, which will clog hoppers and result in poor distribution.

in vigor, which may be a critical factor if weather is bad while the seed is germinating in the field. It is not known how much seed can deteriorate before it becomes risky to use. Unquestionably, however, high-quality seed is essential for consistent success, and increasing the sowing rate is not a good substitute.

Most landowners have the dealer coat the seed with repellents at an extra cost. This treatment will add about 8 percent to the weight. It is advisable to negotiate the cost of treatment separately rather than to pay one price for treated seed. When the dealer is to coat the seed, the purchaser should specify exactly what is desired—i.e., the amount of each ingredient, the manufacturer, and treating methods. It is not sufficient to order "repellent-treated seed."

Stored seed can be used if high viability is maintained (Barnett 1964, 1969). The former belief that fresh seed was essential originated from a number of failures in which badly deteriorated lots of stored seed were sown. Research has shown that longleaf seed can be kept for as long as 10 years with no serious loss of quality, and lots kept for several years have been successfully used in a number of commercial operations. When buying seed held in cold storage it is important to have a germination test conducted before the sale is finalized.

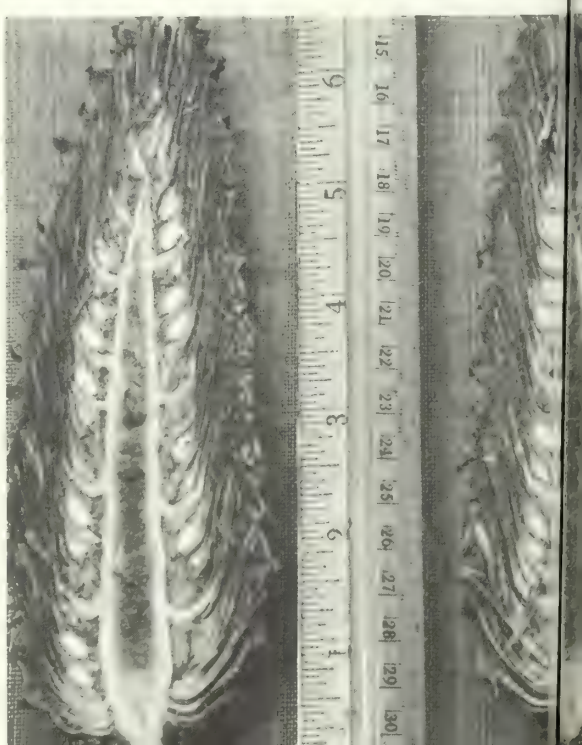
More and more landowners are collecting their own cones and having them processed in a commercial kiln. This method permits procurement of seed from preferable zones, and cones can be obtained from trees of above-average form and vigor. Costs of kilning cones and processing seed range from $1.00 to $1.25 per bushel of cones.

It is also feasible for landowners to process their own cones. Although specialized equipment is required, capital investments can be recove if 4,000 bushels are processed. A small, forc draft kiln that can be constructed for $2,(will handle 1,000 bushels in a single seas Equipment for dewinging and cleaning costs additional $500. Improvised facilities are ap be inefficient and harmful to the seed.

Collecting or buying cones may be an pensive way to obtain seed unless certain cautions are taken. Seed yield per bushel of co varies widely, and low yields inflate costs s stantially. Yields can be forecast several mor before collecting by cutting sample cones lo tudinally, counting the full seeds on the expo surface, and determining the average yield bushel of cones from the following tabula (McLemore 1962):

Number of full seeds exposed	Estimated yield of full seeds-	
	Number per cone	Pounds per bushe
2	23	0.36
4	35	.56
6	47	.75
8	59	.94
10	71	1.14
12	83	1.32
14	96	1.53
16	108	1.73
18	120	1.92

Slicing cones longitudinally and counting the number o seeds excised is the basis for predicting seed yields.



Fairly accurate estimates can be obtained by aking two cones from each of 20 trees. Seed ields in the tabulation were computed by asuming an average of 80 cones per bushel and ,000 seeds per pound. Since the size of cones aries considerably, estimates can be improved y measuring the number of cones per bushel. his should be done only after cones have eached their full size.

Costs can be reduced substantially by collectng in bumper years and storing for use in lean ears. Not only are cones cheapest when they re most abundant, but seed yields are greatest. n years of heavy crops, yields may average more han 1 pound of seed per bushel, as contrasted o ½ or ¾ pound when cones are scarce.

Successful storage of seed depends on several actors. First, cones should be picked only after ests have shown them to be ripe. Earlier colection results in lower yields and seed that deeriorates relatively fast in storage. Second, cones hould be processed within 30 days after colection and seed put into cold storage immediately. Seed from cones held more than a month oses germinability rapidly in storage even when otherwise handled properly. Finally, seed should e dried to 8 to 10 percent moisture content and eld in sealed containers at a temperature beween 0° and 34° F.

SEED TREATMENT

Pregermination Treatment

Longleaf seed germinates rapidly and completely when conditions are favorable. Therefore, t never requires cold stratification or other treatment to improve germination.

Repellents for Coating Seed

The components of the seed coating are a bird epellent, a chemical for controlling insects and odents, a sticker, and an overcoating of powdered aluminum (Derr 1964).

Over the past 15 years, Morkit, sublimed anthraquinone, Arasan, and Arasan-75 have all been used successfully as bird repellents.[1] Because it is not irritating to the skin and mucous membranes, anthraquinone was suggested for hand sowing until recently. Arasan 42-S, a liquid hiram formulation, is now recommended for ll species regardless of the method of sowing. It provides a durable, dust-free coating that is superior to any previous formulation. Furthermore, it is easier and more foolproof to apply. The other components must still be added.

Knowledge of the repellents and how they act against predators is important for proper seed handling and appraisal of seed losses. It is also important in dealing with the public. Thiram, the active ingredient in Arasan 42-S, is manufactured by a number of companies. It is used extensively as a seed disinfectant and fungicide, and is applied to many seeds sold to home gardeners. Thiram has very low toxicity, but it is irritating to man. It repels most birds immediately; a few ingest one or two seeds before they reject it. Rabbits are also repelled. Mice and other small animals will eat seed treated with Arasan, although their preference for it may be low. Many insects and large mammals are unaffected.

Endrin is added to the seed coating as a deterrent to insects and rodents. The recommended dosage of endrin is 0.5 percent effective. It is highly poisonous and requires careful handling even with the small amount put in the repellent mixture. Studies in many portions of the South have invariably shown that rodents number from 10-15 per acre. Since half this number will destroy a seeding, endrin is almost always needed in the formulation. Moreover, endrin protects seed from many species of insects, which are often numerous. Rodents ingest three to eight seeds, depending on the size of the animal, and then will take no more. They are not killed—rather, a sublethal dose conditions them from eating additional treated seed. This is a desirable reaction because it precludes invasion of the area by new animals, as would occur if the coating were lethal to rodents. With the number of seeds normally ingested, birds are not harmed. Endrin should never be used alone because it will endanger birds that are repelled by the Arasan. The effect on insects varies—some are repelled, some die after contact with treated seed, and some destroy the seed without serious exposure to the chemical.

Whenever it is planned to use endrin in the formulation it is advisable to review seeding projects with the fish and wildlife and the health departments of the State in which the seeding is planned. The purpose of the review should be to determine possible adverse effects on nontar-

[1] Here and on following pages, mention of trade names is solely for information, and implies no approval of products to the exclusion of others that may also be suitable.

get organisms, streams, and water supplies, and to take positive steps to minimize any dangers.

Dow Latex 612 is used as a sticker to hold the repellents to the seedcoat. It has no effect on predators. The last ingredient of the coating is aluminum powder, which lubricates seeds for easy flow through machines and prevents clustering. Aluminum has no repellent properties.

Applying Repellents

Arasan 42-S contains 4 pounds of thiram per gallon. Two gallons will treat approximately 100 pounds of dry seed. When the latex sticker and endrin are added to Arasan 42-S, the total quantity needed to coat 100 pounds of seed is 2.2 to 2.4 gallons. The procedure described here has proved efficient for 5-gallon batches, though smaller amounts can be prepared similarly:

Place 2½ pounds of Stauffer's Endrin 50-W in a clean 5-gallon container, add 2½ gallons of Arasan 42-S, and stir with a paddle until the powder is thoroughly wet and free of dust. This is the most difficult step in the entire process. **CAUTION: Wear rubber gloves. Use a respirator or work out-of-doors where inhalation of endrin dust can be avoided. Dispose of empty containers so that animals and humans cannot come in contact with them.**

Beat with a paint mixer powered with an electric drill running at 1,200 r.p.m. until the mixture is smooth and free of lumps. This operation takes about 2 minutes.

Mix 25 fluid ounces (about 1½ pints) of undiluted Dow Latex 612 with another 2½ gallons of Arasan 42-S.

Blend the two mixtures together by pouring from can to can about 10 times.

The final mixture totals about 6 gallons. It is a stable suspension, but if prepared several days beforehand it should be stirred thoroughly before application.

About 1.2 gallons of the total repellent mixture are needed for 50 pounds of seed. The first batches should be examined carefully to determine if all seeds are fully coated. The best procedure is to start with a slight excess, then gradually cut back until a complete coating is obtained with no surplus. If too much is applied, dried seeds will stick together in large clumps.

The rolling-tumbling action of a small concrete mixer is very effective for applying the coating. Fifty-pound batches of seed can be treated in a 3¼-cubic-foot mixer in approximately 3 minutes. A three-man crew can treat a ton of seed daily.

Coating is accomplished by placing a weighed amount of seed in the mixer, then adding the measured amount of the liquid repellent while the mixer is turning. After 2 minutes of tumbling, aluminum powder is added at the rate of 8 tablespoons per 50 pounds of seed, and the mixer is allowed to turn for another minute. Treated seed should be spread out 3 to 4 inches deep for drying. It should be raked periodically to hasten drying and reduce clustering. The seed is dry enough to pick up and put in sacks when the coating changes color from gray to white. In clear weather, the coating will dry thoroughly in 3 to 4 hours.

Lots of 2 to 5 pounds can be treated by mixing with a ladle in an open container such as a lard can. Approximately 3 fluid ounces of repellent mixture are required per pound of seed. An aluminum overcoating can be obtained by adding 1 teaspoon of the powder to the seed and stirring for another 30 seconds. Seed should then be spread out to dry.

Whether it is applied by the landowner or a commercial dealer, the repellent coating should be checked for durability before sowing begins. The test is made by putting several hundred dry seeds in a small wire basket and running a full stream of cold water from a faucet over them for 2 minutes. If two-thirds of each seed remain coated, the repellents will weather satisfactorily in the field. If the loss is greater, application was improper and the seed should be washed to remove as much of the coating as possible, and then recoated.

Certain precautions are necessary when storing the sticker and the chemical repellents. The latex sticker is a suspension that is easily broken if stored in an uncoated metal container or subjected to temperatures below 32° F. or above 110° F. If the suspension is broken, the latex loses all adhesive properties and the repellents are quickly washed off in rains. Several serious failures have been traced to improper handling of latex. Arasan 42-S and Endrin 50-W should be stored in their original containers, which should be tightly closed. It is a good policy not to keep these chemicals for more than 1 year. Unused chemicals that have been mixed together should be discarded each season.

Directions for preparing repellent and applying it to seed:

½ pounds of Endrin 50-W
gallons of Arasan 42-S.

Stir with wooden paddle.

Beat with paint stirrer.

5 fluid ounces of undi-
Dow Latex 612 to an-
½ gallons of Arasan 42-S.

Blend by pouring from can to can about 10 times.

Pour finished repellent directly onto seed as mixer is turning. Tumble for about 2 minutes.

Add aluminum powder and tumble for another minute.

Seed is fully coated; it should be spread out to dry.

The coating on these seeds was checked by washing them under a full stream of water from a faucet for several minutes. Seeds on left retained repellents satisfactorily, while those on right lost too much.

Holding Repellent-Treated Seed

Operations should be carefully scheduled to minimize time between treating and sowing. Some delay is unavoidable, however, especially when seed must be shipped or bad weather interrupts sowing.

Seed treated with repellents can be stored for several weeks in a well-ventilated, unheated building or in a cold room at any temperature down to 0° F. Sacks should be placed so that air circulates around each one. If the seed must be kept until the following year, it should be dried to 10 percent moisture and stored at 0° to 25° F. The repellent coating will not lose its effectiveness even after 1 year of storage.

TIME OF SOWING

Fall sowing of longleaf pine has been recommended for a number of years, except in a few unusual situations. Recent research, however, indicates that late winter may be preferable on many sites. The decision about season must rest on careful appraisal of several factors.

Sites subject to frost heaving should be sown in the late winter. The damage occurs most often on heavy soils with sparse vegetative cover. On such soils repeated freezing and thawing is likely to lift small, fall-germinated seedlings out of the ground.

Clipping of newly germinated seedlings near the groundline is greater in fall than in spring sowing. Studies in central Louisiana have clearly shown that most clipping can be avoided by sowing in late winter. The damage is done primarily by rabbits when other green vegetation is scarce. Losses, which average about 25 percent during the winter, have exceeded 75 perce in some situations. Consequently, February so ing should be preferred if clipping has be severe in the past or if the rabbit population high.

Areas subject to early spring droughts shou be sown in the fall, to give seedlings time to c velop good root systems before dry weather se in. When heavy clipping and early droughts c both probable, fall is the better choice for sowir

The optimum time for fall sowing is as so as soil moisture is adequate for prompt germin tion and maximum daytime temperatures dr below 85° F. Over much of the range of lon leaf, the beginning of regular frontal storms the best time. The storms are accompanied rain, and summer temperatures begin to mo erate. In the Gulf Coast region, this may occ from late October to early December, but us ally conditions are satisfactory by the middle November.

Sowing too far in advance of the optimu time is risky. Longleaf seed will not germin when temperatures exceed 85° to 90° F., a it deteriorates rapidly in hot weather. Delay sowing is also hazardous, as germination is v slow below 50° F. and seeds with radicles beg ning to penetrate the soil are subject to upro ing and washing in heavy rains. Consequent the timing is critical. The optimum period lo for only a few weeks. The best procedure is sow quickly when soil moisture and temperatu are conducive to prompt, fast germination.

With spring sowing, temperature is the m consideration, since winter rains have usu recharged the soils. In the lower Coastal Pl sowing should be done in early February. I more desirable to sow too early than too l Even if low temperatures occur, they will be short duration, and preferable to high tempe tures. Hot weather, which stops germination spoils seed, must be avoided.

METHODS OF SOWING

Longleaf, like most other southern pines, been sown by a number of hand and mach methods. The choice often depends on the of the area, soil and cover conditions, the tern of stocking desired, and the facilities a able to the landowner.

and Sowing

Hand methods are useful primarily on small acts. If the site is disked in strips, seed can broadcast or placed in spots on the prepared round. One man can cover about 15 acres when attering seed, and 5 acres when spotting. Both ethods conserve seed by confining it to the rips. Rubber gloves must be worn when han- ing treated seed.

Spotting has been successful on both open rassy sites and beneath hardwoods. Five or six eeds are dropped on a clear spot or a spot raked ee of leaves. Seeds can be covered lightly with il. To prevent blowback, leaves raked from ots should be scattered, rather than left in a le on the edge of the spot. From 1,000 to 200 spots per acre are needed, depending on nvironmental conditions and stocking objectives.

Most tools for spotting have a device for baring ineral soil and a mechanism for metering a redetermined number of seeds on the prepared ot. They sell for $15 to $30. Each model has eatures that adapt it to special soil and cover onditions. For most small operations, a short- andled firerake and an apron for carrying seed re adequate.

A hand-operated cyclone grain seeder is ell suited for tracts up to 200 acres in size. It especially useful on irregularly shaped areas hat are difficult to sow from the air, and on acts where patches of established pines are to be bypassed. Crews can be trained quickly to broadcast seed uniformly, and one man can cover 15 acres daily where brush and terrain are moderate.

Formerly a major disadvantage of the hand-operated seeder was exposure of personnel to the chemical dust from the repellent coating. With Arasan 42-S, however, the coating is essentially dust-free.

Tractor Seeding

Many tractor seeders have been developed over the past 10 years. Since they are numerous and diverse, only those that have been tried extensively will be described.

Power-driven cyclone grain seeders are sometimes mounted on a tractor. The swath width is generally about 40 feet, and a small tractor can cover from 30 to 40 acres daily. This broadcast method is efficient in dense brush where hand-operated seeders are impractical. It is dangerous on steep terrain.

Tractors have also been equipped to sow in rows on strips disked in the summer. Ordinarily twin grain hoppers are mounted on the rear of a tractor, and the metering plates are activated by a drive wheel that is in contact with the ground. Packing wheels are sometimes mounted to firm the soil in front of and behind the seed drop. Rubber-tired and crawler tractors have been used.

About 15 acres per man-day can be broadcast-sown with a hand-operated grain seeder.

A furrow seeder that operates behind a conventional fireplow. Adjustable hillers elevate a ridged bed in the center of the furrow to prevent washing and flooding of the seeds.

Tractor-drawn machines have been developed to prepare beds and sow in rows in a single operation. They form beds by plowing furrows, disking, or rotatilling narrow strips.

Furrow seeders are the most common (Croker 1964). They are of two types; one has a middle-buster plow pulled by a tractor, the other has a plow mounted on the front of a tractor.

Those pulled by a tractor plow a shallow furrow and elevate a narrow mound in the center of the furrow with a set of hillers. Seeds are dropped from a hopper at predetermined intervals onto the mound and pressed firmly into the soil by a packing wheel. The slight elevation of the bed prevents seeds from being washed away or submerged for long periods; pressing the seed into the soil surface improves germination. The method is not suited to poorly drained soils, for the furrows flood in heavy rains. It is also impractical in dense stands of hardwoods.

In another model designed for deep, sandy soils where seed must be covered to obtain complete germination, the hillers are replaced by an agricultural sword. The sword opens a narrow slit for the seeds within the furrow, but up the slope and away from the bottom where water runs, and a packing wheel covers them with soil. This machine is limited to open, grassy areas, as the sword is easily bent or broken by tree roots.

Front-end furrow seeders also work best o sandy soils with good internal drainage. The are more rugged than the trailing type, howeve and operate well in brushy hardwood stands. On model, used extensively on the Savannah Rive Project of the Atomic Energy Commission i South Carolina, sows directly in the center of furrow. Seeds are dropped from a hopper into very narrow trench cut about ½-inch deep. Sub sequent rains wash sand over the seed, and th light covering facilitates germination. In den brush the machine uproots and kills 50 to 7 percent of the hardwoods while sowing on ideal bed. It is one of the most successful m chines developed so far for sandy soils.

Another front-end furrow seeder has a cu away V-plow that pushes a ridge of soil direct into the path of each tractor track. The weig of the tractor packs the loose soil, and seeds a sown on each ridge from hoppers mounted the rear of the tractor. A hopper just behi the plow point can be operated to drop se in the furrow as well.

Furrow seeders are capable of sowing fr 15 to 20 acres per day. Their main advanta is low cost per acre, resulting from efficient d tribution of seed and from the combination bed preparation and sowing into one operati Establishing trees in rows may also be an

front-end furrow seeder, with seed hopper immediately be-
nd the point of the V-blade, operates effectively in dense
brush.

ntage, provided that close in-row spacing is
t objectionable. Disadvantages include: (1)
gh capital outlay for tractors and machines,
) low average daily production of seeders, which
nnot operate in severe weather, (3) the temp-
tion to sow far beyond the optimum date to
ilize machine fully and to meet production
als, (4) rough condition of the ground after
eding, (5) displacement of topsoil—a particu-
r drawback on sites where fertility is low, and
) limitation to sandy, level sites, and with
me models to cleared or open sites.

Disk seeders that prepare flat beds were first
veloped to sow two rows simultaneously with
e same tractor power required for a one-row
rrow seeder. Later a single-row model was made for maneuverability in hardwood stands. Two offset disk units, each about 1½-feet wide, are mounted about 4½-feet apart, edge to edge. A packing wheel and seed hopper and funnel are located behind each set of disks. Behind a light crawler tractor the dual unit can sow about 30 acres per day. This machine is adaptable to a broad array of soils. Sowing rates must be higher than with furrow seeders, because considerable seed is lost by silting even where disked soil has settled for several months. Moreover, disking in the cool, wet part of the year fails to control competing grasses satisfactorily. Otherwise, advantages and disadvantages are the same as with furrow seeders.

For wet soils that require thorough preparation by chopping and disking, a modified disk seeder has been developed. It elevates a narrow ridge that prevents flooding. The components are a pair of two-blade disks set in a hilling position, two packing wheels, and a seeder that is positioned to drop seed between the wheels. The units can be operated in pairs behind a light crawler tractor.

Aerial Seeding

Aircraft seeding is a widely used and proven method for reforesting large acreages rapidly and at minimum cost. It requires the least effort and capital outlay by the landowner; in most cases he is only required to furnish accurate maps of the area to be seeded, technical supervision, and personnel for ground control of the aircraft. Accurate work has been done consistently both with small fixed-wing airplanes and with helicopters.

A 2-row disk seeder that sows approximately 20 acres daily.

Aircraft of both types require special distributing equipment that must be calibrated accurately, especially for longleaf with its irregular-shaped wing stubs. In addition, accuracy requires uniform flying speed and altitude, and constant checking by the pilot for stoppage or malfunction of equipment. The landowner should establish, in advance, flagging positions that will insure straight flight lines. Many areas have been sown with flagmen pacing off the flight lines, but results are usually unsatisfactory.

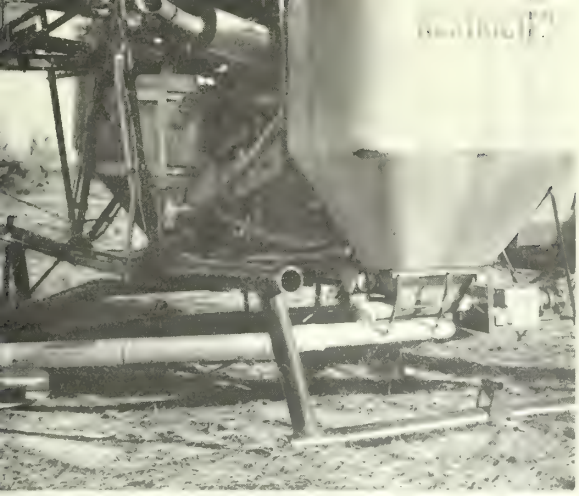
Fixed-wing airplane.—The light monoplane is the only type of fixed-wing aircraft that has been used extensively. It is highly maneuverable and it can operate from short unimproved runways—often constructed on the area to be seeded. Depending on the size and shape of the areas, and on the distance from a landing strip, planes can seed from 150 to 200 acres per hour.

Most planes used in agricultural work can be adapted for pine seeding at a cost of about $100. Modification is needed because the long, adjustable opening between the distributor and the hopper is too narrow for an even flow of seed. Plates set in the bottom of the hopper block off part of the aperture, permitting a wider setting.

Flight strips should not exceed 66 feet in width. At normal flying speeds and altitudes the distributor throws seed about 40 feet each side of the plane. Some overlapping of adjoining flights is necessary to prevent skips and to even out the distribution near the outer edges of the seed pattern.

Helicopter.—A light helicopter can operate from a small clearing on the area to be seeded. It thus has an advantage when a fixed-wing plane would have to travel a considerable distance to a landing strip. Otherwise the differences between the two types of aircraft are small and the choice often depends on the bid price. The helicopter's landing capability gives it a higher average production rate of 250 to 300 acres per hour, which reduces the cost of flagging and

A helicopter can sow 3,000 acres per day.



e revolving slinger on a helicopter distributes seed over a 99-foot swath.

ıer services provided by the landowner and rmits a slightly higher contract price per acre. A helicopter must be equipped with a power-ven centrifugal slinger for distributing the seed. must also have a positive, motor-driven meter dispensing seed from the hoppers into the ıger. The types in use will cover a 99-foot ath. When properly adjusted they distribute ed accurately.

RATE OF SOWING

Optimum sowing rates vary by method of sow-, soil condition, cover, site preparation, preda- populations, stocking objectives, climate, and wn-spot hazard (Miller 1966). Most landowners ve employed a single rate for each method of ving. A few large landowners have initiated scription sowing, adjusting rates in the light experience with particular conditions. This ctice will increase as landowners expand ir operations and gain confidence in seeding hniques.

In the West Gulf region, recommended rates acre for initial trials are 3 pounds for broad-t sowing, 2 pounds for disk seeding, and 1½ nds for furrow seeding. The rates can be re-ed about 35 percent on moist sites in the utheast, where initial establishment and first-r survival are generally higher. These weights for dry seed that has not been coated with ellents. They assume viability of at least 80 cent, and must be increased proportionately germination is lower.

Well-cleaned longleaf seed averages about 00 per pound. In commercial operations in-l establishment has averaged about 30 per-nt in Louisiana and Mississippi and 50 percent good sites in Florida and Georgia. These tree percentages are equivalent to 3,000 to 5,000 seedlings per acre from 3 pounds or 10,000 viable seed.

Offhand these levels may seem high, but only about one seedling in three starts height growth and reaches sapling size. First-summer mortality, especially in the westerly portion of the range, may reach 50 percent in dry years. Brownspot infection and prescribed fires for disease control also reduce stocking; roughly half of the seedlings surviving the first year initiate height growth. The best insurance against understocking is to maintain sowing rates high enough to offset unusually large losses. Experience suggests that on good sites initial stocking in the spring following seeding should be at least 2,000 well-distributed seedlings per acre. On poor sites 3,000 seedlings are needed because first-summer mortality will be higher and losses to disease greater. With intensive site preparation, these stocking goals can be lowered by 25 percent.

To economize, some landowners have reduced sowing rates by as much as 50 percent. Reductions like this should be made only with the full understanding that they lessen the chances for success.

CALIBRATING SOWING EQUIPMENT

Faulty distribution of seed may result in irregular stocking and partial failure even though seedling establishment and survival are high. All of the machines described in the previous section can be adjusted to sow longleaf pine accurately and uniformly if the repellent coating is dry and the seed is free of trash. Screening seed through ½-inch hardware cloth immediately before placing it in the hopper will insure against clogging, which is the most common cause of poor distribution. Wet or sticky seed will not flow freely; hence the repellent coating must be dried thoroughly and kept dry in the field.

Sowing rates should be based on the weight of uncoated seed. The repellent coating will increase weight by 8 to 10 percent. Consequently, it is necessary to sow 3.3 pounds of coated seed to obtain a 3-pound rate. Because weight gains vary with the initial moisture content of seed and the method used to dry the repellent coating, it is desirable to determine the weight ratio of dry to treated seed for each job.

Tractor-drawn machines are calibrated by checking the number of seeds dropped on 100-foot segments of prepared beds. For example, a rate of 1½ pounds per gross acre on plowed furrows spaced 8 feet apart (center to center) requires 124 seeds on a 100-foot segment, provided that the lot contains 4,500 seeds per pound.

Machines for broadcast sowing—aircraft and cyclone seeders—are calibrated and checked by a system of area control. A predetermined quantity of seed is sown on an area of known size, and it is assumed that distribution is uniform over the entire area. An advantage of the method is that a constant check can be kept of the sowing rate as the job progresses, provided that the area in each flight strip is known. Seed-trap boxes, hoed spots, and other methods of appraising distribution have never been satisfactory in regulating rates, for it is seldom practical to inspect enough spots in the short time available for calibrating an airplane.

Fixed-wing airplanes can be calibrated as follows:

Determine the weight of treated seed to be broadcast per acre.

Select three tracts, each 20 to 40 acres in size and with regular boundaries, for calibration trials. Mark 1-chain flight strips on two ends of each tract to guide flagmen. A 66-foot swath gives excellent seed distribution with all types of airplanes now available.

Carefully check to determine if hopper gate opens to the same width each time it is opened. Loose linkage has been a common cause of erratic distribution.

If the pilot has experience with all species and rates, let him choose the size of hopper opening.

Weigh seed for 20- or 40-acre trial. Add 20 pounds extra for a buffer. Screen all seed before it is put in the hopper.

Sow the area, flying crosswind at a steady, normal speed. Flying parallel to the wind is satisfactory if the pilot can adjust his airspeed to maintain a fairly constant ground speed in both directions. Never calibrate when winds are gusty, shifting, or above 8 m.p.h.

Weigh seed remaining in the hopper to determine if rate was accurate. Adjust gate opening accordingly and sow another test area. Ordinarily the correct setting will be obtained in two or three trials.

After calibration, begin regular operations and steadily increase the area sown on each flight to about 100 acres. Because mistakes in the sowing rate are impossible to correct, seeding more than 100 acres per flight is an unnecessary risk. Costs of flying will not be increased appreciably by limiting the acreage per flight to a reasonable level.

Other broadcast machines are calibrated in th same manner. The effective swath is 99 feet f helicopters, 16 feet for hand seeders, and abo 40 feet for tractor-mounted seeders. A trial ar of ½ acre, or a single swath ¼-mile long, adequate for hand machines. Five acres, t equivalent of a 40-foot swath 5,450 feet long, a needed for tractor-mounted seeders. A hopp opening of 1/3 inch, which is the approxim width of a coated longleaf pine seed, is a go starting point when calibrating cyclone seede

Minor adjustments in hopper openings oft become necessary during the day, because mo ture in the repellent coating varies with chang in relative humidity. If the coating becomes t wet the seed will not flow freely even if openin are increased, and the only recourse is to st flying until the coating can be dried.

Most operations have been executed by flyi crosswind, since a steady ground speed is n essary for uniform distribution. Crosswinds up about 8 miles per hour have no appreciable fect on the swath width, but they shorten the d tribution upwind and lengthen it downwi Stronger crosswinds cause windrowing of seed. Sowing should not be attempted when wi are gusty, for the course of the aircraft is lik to be irregular and differential drift of seed give erratic distribution. If pre-established fli lines necessitate flying with a paralleling wi the airspeed should be regulated to give a u form ground speed. Variable or shifting wi cannot be tolerated regardless of the direct of flight.

The landowner should retain sole responsibi for specifying the amount of seed to be bro cast on each flight and for determining wh the weather is unsuitable for sowing. Contr for aerial services should state these facts clea

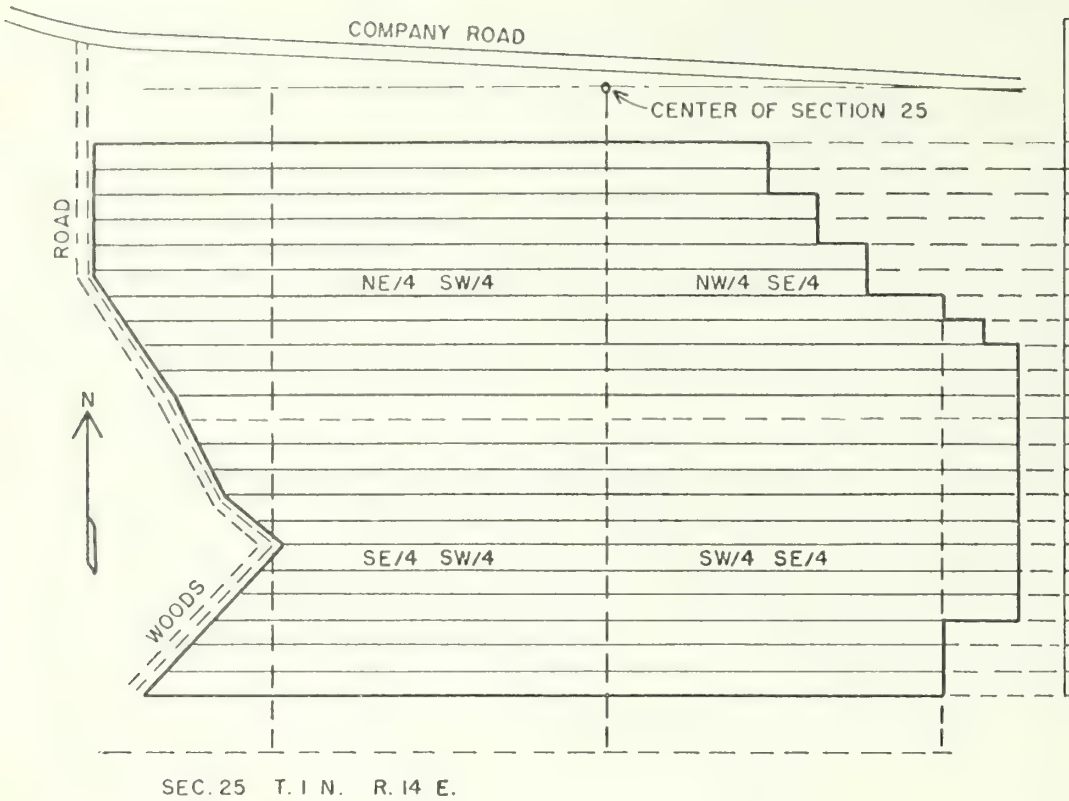
Seeding aerially in a heavy crosswind caused distinct windrowing of this longleaf stand.

A plane's altitude has limited effect on swath dth. At heights of 80 to 125 feet, distribution good if ridges are cleared by 60 feet. Below s level, strip width narrows excessively. Heli- ters can operate as low as 10 to 20 feet, be- use the seed is thrown out by the slinger.

Flight strips are guided by flagmen on the und. For accurate alignment the pilot needs see at least two flags, other than the one ectly below the ship, after completing each n. Three flagmen are usually enough, although re may be needed if strips are long, terrain rolling, or trees obstruct the pilot's vision. e flagman should be stationed at each end the flight strip. Insofar as possible, flagmen uld be on ridges and along roads or other enings. Flags, mounted on long bamboo poles, uld be a distinctive color and should be ved back and forth as the aircraft approaches. It is best to measure and mark flagging points the ground in advance. Flagmen often get out alignment if they are required to pace off dis- ces between strips as the operation progresses.

A map showing flight lines and the acreage each swath facilitates the entire operation (see wing). With this information the acreage to

Placement of flagmen is important for good distribution; the pilot must see at least 2 flags at the start of each swath.



STRIP NUMBER	ACRES PER STRIP	ACRES IN 10-STRIP
1	5.8	
2	5.8	
3	6.3	
4	6.3	
5	6.8	
6	6.6	
7	7.3	
8	7.4	
9	7.5	
10	7.4	67.
11	7.3	
12	7.2	
13	7.2	
14	7.1	
15	6.9	
16	6.6	
17	6.4	
18	6.6	
19	6.8	
20	6.5	68
21	6.8	
22	7.0	13.
	149.6	149

be sown during each flight and the amount of seed needed can be quickly determined, and the pilot can be told how many strips to fly before returning.

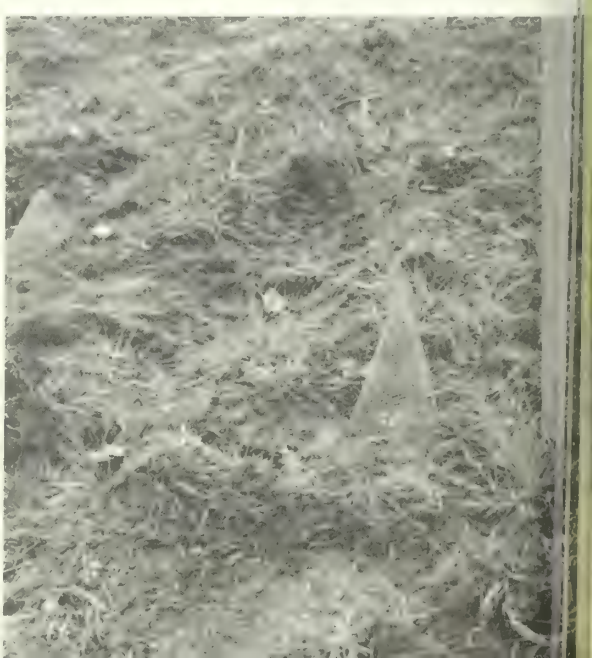
Despite precautions, hoppers will sometimes become clogged and the aircraft will return with an excessive amount of seed. The question, then, is where the stoppage occurred. Sometimes this information can be obtained from the flagmen. Otherwise, the best course may be to refly every second or every third strip, depending on the quantity of seed to be sown; altitude should be 200 to 300 feet. Reflying requires good communications with the flagmen.

CHECKING DEPREDATIONS

The landowner just starting a direct-seeding program should make frequent, systematic inspections during the germination period. It is the only way to determine if unusual losses are occurring and to establish why an operation fails. These examinations are not needed if several seedings in the same general area have been successful.

Seed is often difficult to find after it has been exposed to several rains. It is widely scattered, and some of it is covered with soil and debr A series of small observation stations, sown w extra seed, is the only practical way to fol the progress of germination and to appra losses. A satisfactory station consists of an id tification stake, 50 seeds sown within 18 inc of the stake, and one or two seeded sp screened to exclude birds and rodents. Scree

An efficient observation station, consisting of exposed covered seed close to a numbered stake.



ots should be on level ground where the seeds nnot wash away. Window screening or ¼-inch rdware cloth makes a satisfactory cover if nned down firmly. If stations are well distrib-ed over the seeded area they will indicate stribution of predators, extent of damage, and ether or not stocking is adequate. Twenty-five e sufficient for areas up to several hundred res; 50 are needed for tracts of 1,000 acres larger. One man can usually examine 50 in day.

Stations should be checked weekly until most the seeds have germinated. Progress of ger-nation, number of intact seeds and seed hulls und, type of damage to seed and seedlings, ect activity, and condition of the repellent ating should be noted for each station. Ger-nating seeds should be marked with pins to ect losses that may occur during advanced ges of germination.

Some birds and insects, crayfish, and large mmals take longleaf seed whole, leaving no nnants for identification. Tracks or droppings y afford a clue to their identity. Many other dators leave characteristic hull and frag-nts behind. Some rodents carry seeds a few ds to protective cover; characteristically, they ve a neat pile of seed hulls where they have n feeding.

Some predators, among which rabbits and ckets are the chief suspects, clip new seedlings near the groundline and carry away or eat severed portion. All that remains is a short b, ⅛ to ¼ inch high, which is easily over-ked unless the seed or seedling is pinned soon er germination begins. Clipping is most preva-t in January and February, and the first dlings to become established are the most nerable. As previously mentioned, seedlings rminating in the fall are damaged more than se started in the spring. If crickets are the use, pieces of the cotyledons can be found in upper food storage chamber of their burrows. bbits consume seedlings immediately after pping them.

Harvester ants carry large numbers of seeds o their nests. Town ants take portions of ger-nating seed and sections of seedlings to their onies. Several other species of ants cause nor damage by feeding on radicles or on endo-rms after the seed cracks open in the early ges of germination.

Caterpillars, centipedes, and millipedes occa-sionally feed on seed and seedlings, but their combined damage is ordinarily less than 5 percent.

APPRAISAL OF STOCKING

Two systematic inventories should be made by those starting seeding operations. They should be independent of the observation plots used to determine seed and seedling losses. The first should be made as soon as germination is com-plete in February or April, depending on the season of sowing. Coupled with observations during the germination period, it will indicate the efficiency of repellents, severity of predation, and effect of weather on seedling establishment. A second inventory, preferably on the same sam-ple plots used for the first, is needed at the end of the first growing season to appraise mortality and overall success. After experience is gained, the early inventory may be omitted.

The number of plots depends on the accuracy desired and the plot-to-plot variation (expressed as the coefficient of variation) in number of seed-lings. Size of area seeded and size of sample plot influence the coefficient of variation. Ex-perience indicates that, with plots 0.001-acre in size, a coefficient of variation of 100 percent may safely be assumed for areas up to several thousand acres. The formula for computing in-tensity of sampling with 67-percent reliability is:

$$\text{Sample plots needed} = \left\{\frac{\text{coefficient of variation}}{\text{accuracy desired}}\right\}^2$$

If a landowner chooses to sample for ± 10 percent accuracy, the number of plots would be:

$$\left\{\frac{100}{10}\right\}^2 = 100.$$

On a large area, 100 plots give an overall appraisal of stocking but no information on the location or prevalence of areas that are inade-quately stocked. If, for example, it is desired to know whether stocking is sufficient on each 40-acre tract on a 1,000-acre area, each forty must be inventoried with 100 sample plots. The usual procedure is merely to sample the entire area, and wait until the trees are 3 or 4 years old to visually detect portions that need supplemental planting or seeding.

When seeding rates, methods of sowing, or sites vary within an area, it is desirable to inventory homogeneous subblocks separately.

For broadcast sowing, circular milacre (0.001 acre) plots equally spaced over the area are satisfactory. Average plot stocking multiplied by 1,000 provides an estimate of seedlings per acre. Distribution is expressed as the proportion of sample plots with one or more seedlings. These two statistics are closely related: adequate distribution is rarely obtained with less than 750 seedlings per acre. Both values are useful, however, and counting the seedlings takes little extra time once the plot has been located. A high average number of seedlings per acre and low sample plot stocking indicate uneven sowing or varying seedling establishment. Proportion of stocked milacres is the statistic most valuable for evaluating results—50 to 55 percent is commonly taken as the minimum for a successful operation.

Estimates on broadcast-sown disked strips require a modified technique. Two milacres—one on a disked strip and one on an undisked balk—are used at each sample location. The edge-to-edge distance between disked strips at each location is measured to determine the proportion of the area that is disked. To calculate overall stocking, average stocking on disked and undisked milacres is weighted by the area represented by each.

Where sowing is confined to rows, as on plowed furrows or on disked strips, inventories are made differently from those on broadcast areas. Sample plots, located over the entire area, consist of a 13.2-foot segment of a row or strip. Each plot is divided into two 6.6-foot subplots, and the number of seedlings on each is recorded separately. Distances from the center of the sample strip to the center of each adjoining strip are measured at each location to adjust average stocking to a gross acre. Seedlings per gross acre are estimated by multiplying the average stocking for 13.2-foot plots by

$$\frac{3{,}300}{\text{average distance between row or strip centers}}$$

Thus, if average stocking per 13.2-foot plot is five and row centers are 10 feet apart:

$$5 \times \frac{3{,}300}{10} = 1{,}650 \text{ seedlings per acre.}$$

The constant, 3,300, is derived by dividing 43,560 (square feet per acre) by 13.2. If the size of the sample plot is changed, a new constant must be calculated.

Stocking percent based on 1,000 perfectly spaced seedlings per acre is obtained by multiplying the percent of subplots stocked (6.6-foot segments of strip) by

$$\frac{6.6}{\text{average distance between strip centers}}$$

With this method, full stocking is less than 100 percent when the average distance between strip centers exceed 6.6 feet. Maximum stocking obtainable with strips on 10-foot centers is:

$$100 \times \frac{6.6}{10.0} = 66 \text{ percent.}$$

The effect of strip spacing on subsequent tree distribution should be carefully weighed when planning a seeding operation.

In seed-spot operations the simplest method in inventory is to determine the proportion of spots with at least one seedling. As more than one seedling per spot is excess stocking, it is unimportant to calculate the stand per acre. If the spots cannot be found readily, stocking can be estimated from mechanically spaced milacre plots.

COSTS

Costs, time requirements, and production estimates have been summarized in earlier sections for some phases of the seeding operation. Given here are approximate costs for situations that are most common in the South. Obviously, these will vary by the price of seed, acreage to be sown, expenses for equipment, and even efficiency of landowners. Generally, costs will average about 25 percent less in large than in small operations.

Seed prices, one of the main items of expense, are highly variable. In the past 5 years they have ranged from $1.50 to $3.00 for large lots. An average of $2.75 per pound is used in the following estimates. Addition of $0.30 per pound for repellent treatment brings the total seed cost to $3.05 per pound.

A small landowner who hand-sows only a few acres can usually do the work cheaper than industrial landowners. He may have to pay higher prices for seed, but will save on outlays

vel, supervision, Social Security, insurance, and like.

Data given here are for tracts of 300 to 1,000 es. Labor rates are $1.60 per hour plus $0.50 hour for insurance, Social Security, and transtation. No allowance is included for superon or overhead. All costs are on a per-acre sis.

Aerial broadcast sowing of 3 pounds per acre on open sites that were burned for seedbed preparation:

Burning	$0.35
Seed	9.15
Aerial sowing	.80
Flagging of aircraft	.25
Total	$10.55

Furrow-seeding open or brushy tracts with 1½ pounds per acre at a rate of 12 acres per day. Costs of hardwood control not included:

Burning	$1.00
Seed	4.58
Furrowing and sowing	3.25
Total	$8.83

Aerial sowing of 3 pounds per acre on tracts disked in strips:

Burning	$0.35
Disking	2.50
Seed	9.15
Aerial sowing	.80
Flagging of aircraft	.25
Total	$13.05

Hand-sowing 1.6 pounds per acre on disked strips:

Burning	$0.35
Disking	2.50
Seed	4.88
Distributing seed (15 acres per man-day)	1.67
Total	$9.40

Spot sowing, with six seeds on each of 1,000 spots per acre:

Seed	$4.06
Distributing seed (2½ acres per man-day)	6.40
Total	$10.46

STAND PROTECTION AND MANAGEMENT

Longleaf pine requires more care in early years than any of the other southern pines. But the method of regeneration—whether by natural or artificial techniques—has no influence on the intensity of management that is needed.

Mortality from drought is low after the first year. The big problem is to manage and protect the seedlings so that a well-stocked stand starts height growth quickly.

The seeded area should be inspected at regular intervals for hogs. It is not sufficient to rely solely on a fence, because these animals can penetrate the best of barriers. While looking for hogs the forester can make other observations. Overgrazing by livestock can result in losses from trampling and reduce grass fuels enough to complicate burning for disease control. Reinvasion by town ants and pocket gophers can also be detected and steps taken before serious losses occur.

Cotton rats, not mentioned previously, are believed to inhabit only areas with a heavy grass rough. Burning and other site-preparation treatments cause them to leave when their cover is destroyed. They sometimes become a problem when a new rough forms, but by this time the seedlings may be ready for a brown-spot burn that will again destroy the cover. In rare cases assistance of State game officials may be needed for controlling this pest.

Prescribed burns are usually needed to control brown spot sufficiently for trees to start height growth. Burning solely because the grass growth is heavy is unnecessary. Vigorous seedlings can withstand the competition of dense grass even when they are being enveloped. Scheduling of burns is largely dependent on the severity of brown-spot infection. Predetermined schedules are impractical, as infection varies by geographic location and from year to year.

Brown spot typically develops gradually enough so that it can be kept under observation in regular inspections. Stands seldom have much infection at the end of the first year, but by the second or third year a burn is usually required.

The severity of infection should be appraised as late as possible in the winter. Fall ratings may be misleading, because the disease builds up rapidly from November through January. The best procedure is to conduct a brown-spot survey

Six-year-old longleaf stand in active height growth after two burns for brown-spot control.

on well-distributed milacre plots. Only the best seedling on each sample plot is used to estimate the proportion of needle tissue that is dead. If the overall average is 20 to 30 percent, the stand should be burned in the current season.

A second burn may be needed in 2 or 3 years, especially on poor sites where growth is slow. However, the decision should be made on the basis of another disease survey. Infected see lings that will initiate height growth without f should be rated as having zero infection (Crol 1967).

Burns should be made late in the dorm season—in January, or early February. Fi headfires, set on cold days with steady wind have been used for initial burning with good

A row-seeded stand just emerging from the grass stage at age 3½ years.

s. They are cheaper than backfires, raise und surface temperatures less, and do a bet- job of destroying the pathogen. They can made when fuel moisture is too high for back- s. Large areas can be treated rapidly when ning conditions are stable. Headfires are not isable on areas when the seedling stand is nposed of two age classes—a situation found en reinforcement seeding is done in under- cked natural stands.

f a second burn is needed when a portion of stand is in active height growth, backfires are ommended to avoid killing the most vigorous dlings. Two objectives should be kept in mind en backfiring for brown-spot control. One o keep surface temperatures low—best ac- nplished by firing against a steady wind on cold s. The other is to secure a complete burn. chy burning can result in a rapid reinfection brown spot.

REFERENCES

nett, J. P.
1964. Stored longleaf seed successfully direct seeded. USDA Forest Serv. Tree Planters' Notes 65, pp. 3-5.

nett, J. P.
1969. Long-term storage of longleaf pine seeds. USDA Forest Serv. Tree Planters' Notes 20(2): 22-25.

nett, J. P., and McLemore, B. F.
1966. Repellent-coated pine seed can be stored. Forest Farmer 25(9): 14.

s, W. L., Jr.
1959. Sowing criteria by sites. **In** Direct seeding in the South, 1959, a symposium, pp. 129-135. Duke Univ.

er, W. D.
1964. Longleaf seed losses to animals on burned seedbeds. USDA Forest Serv. Res. Note SO-6, 3 pp. South. Forest Exp. Sta., New Orleans, La.

sady, J. T., Hopkins, W., and Whitaker, L. B.
1955. Cattle grazing damage to pine seedlings. USDA Forest Serv. South. Forest Exp. Sta. Occas. Pap. 141, 14 pp.

ker, T. C., Jr.
1960. The H-C furrow seeder. USDA Forest Serv. Tree Planters' Notes 43. pp. 15-16.

Croker, T. C., Jr.
1964. Two H-C furrow seeders. USDA Forest Serv. Res. Note SO-5, 4 pp. South. Forest Exp. Sta., New Orleans, La.

Croker, T. C., Jr.
1967. Crop-seedling method of planning brown-spot burns in longleaf pine. J. Forest. 65: 488.

Derr, H. J.
1960. Preventing sticker failures in direct seeding. USDA Forest Serv. South. Forest Exp. Sta. South. Forest. Notes 128.

Derr, H. J.
1964. New repellent formulation for direct seeding. J. Forest. 62: 265.

Echols, H. W.
1966. Texas leaf-cutting ant controlled with pelleted mirex bait. J. Econ. Entomol. 59: 628-631.

Evans, T. C.
1959. Field technique for evaluating the success of establishment. **In** Direct seeding in the South, 1959, a symposium, pp. 161-166. Duke Univ.

Lewis, C. H.
1959. The economic advantage of seeding over planting on large ownerships in Louisiana. **In** Direct seeding in the South, 1959, a symposium, pp. 171-177. Duke Univ.

McLemore, B. F.
1959. Cone maturity affects germination of longleaf pine seed. J. Forest. 57: 648-650.

McLemore, B. F.
1961. Prolonged storage of longleaf cones weakens seed. USDA Forest Serv. South. Forest Exp. Sta. South. Forest. Notes 132.

McLemore, B. F.
1961. Small, fast-drying cone kiln. USDA Forest Serv. Tree Planter's Notes 47, pp. 9-12.

McLemore, B. F.
1962. Predicting seed yields of southern pine cones. J. Forest. 60: 639-641.

McLemore, B. F., and Barnett, J. P.
1966. Storing repellent-coated southern pine seed. J. Forest. 64: 619-621.

Mann, W. F., Jr.
1962. Tools for direct seeding. Forest Farmer 21(5): 13-16.

Mann, W. F., Jr.
1965. Progress in direct-seeding the southern pines. **In** Direct seeding in the Northeast, a symposium, 1964: 9-13. Univ. Mass.

Mann, W. F., Jr.
1966. Guides for direct-seeding the southern pines. Forest Farmer 25(7): 99-103.

Mann, W. F., Jr., and Derr, H. J.
1955. Not for the birds. USDA Forest Serv. Tree Planters' Notes 20, pp. 3-6.

Mann, W. F., Jr., and Derr, H. J.
1964. Guides for direct-seeding slash pine. USDA Forest Serv. Res. Pap. SO-12, 27 pp. South. Forest Exp. Sta., New Orleans, La.

Mann, W. F., Jr., and Derr, H. J.
1966. Guidelines for direct-seeding loblolly pine. USDA Forest Serv. South. Forest Exp. Sta. Occas. Pap. 188 re
23 pp.

Miller, S. R.
1966. Prescription direct seeding as
operational program. Proc., Dir
seeding workshops, Alexandria, L
and Tallahassee, Fla., 1965:
109. USDA Forest Serv., Atlar
Ga.

Shipman, R. D.
1963. Seeding depth—its influence on
tablishment of direct-seeded pine
the South Carolina sandhills. J. F
est. 61: 907-912.

Wakeley, P. C.
1954. Planting the southern pines. US
Agr. Monogr. 18, 233 pp.

Wells, O. O.
1969. Results of the southwide pine s
source study through 1968-69. Te
South. Forest Tree Impr. Conf. P
1969: 117-129.

Mann, W. F., Jr.

1970. Direct-seeding longleaf pine. South. Forest Exp. Sta., New Orleans, La. 26 pp. (USDA Forest Serv. Res. Pap. SO-57)

Describes in detail each step from initial planning to final appraisal of results.

Mann, W. F., Jr.

1970. Direct-seeding longleaf pine. South. Forest Exp. Sta., New Orleans, La. 26 pp. (USDA Forest Serv. Res. Pap. SO-57)

Describes in detail each step from initial planning to final appraisal of results.

Mann, W. F., Jr.

1970. Direct-seeding longleaf pine. South. Forest Exp. Sta., New Orleans, La. 26 pp. (USDA Forest Serv. Res. Pap. SO-57)

Describes in detail each step from initial planning to final appraisal of results.

Mann, W. F., Jr.

1970. Direct-seeding longleaf pine. South. Forest Exp. Sta., New Orleans, La. 26 pp. (USDA Forest Serv. Res. Pap. SO-57)

Describes in detail each step from initial planning to final appraisal of results.

Caution!

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key—out of the reach of children and animals, and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the U. S. Department of Agriculture, consult your county agricultural agent or State Extension specialist to be sure the intended use is still registered.

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE

U.S. Department of Agriculture
Forest Service Research Paper SO-58

Wood Machining Abstracts, 1968 and 1969

Charles W. McMillin

SOUTHERN FOREST EXPERIMENT STATION
FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE
1970

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Wood Machining Abstracts, 1968 and 1969

Charles W. McMillin

The purpose of this paper is to abstract significant wood-machining literature that has not been previously listed in English-language texts and bibliographies.[1] The entries mainly represent publications of a research nature, but the author has included trade-journal articles he judged to be of interest. While most of the literature is from 1968 and 1969, an attempt was made to include important papers that had been missed in earlier searches.

Principal sources of information were archival journals in wood science and technology, but *Forestry Abstracts,* published by the Commonwealth Agricultural Bureaux, Farnham Royal, England, and the Bureaux' Current Title Service were invaluable. The search also included the *Abstract Bulletin of the Institute of Paper Chemistry,* the USDA *Bibliography of Agriculture,* and publications lists and annual and periodic reports issued by the regional USDA forest experiment stations and the Forest Products Laboratory, Madison, Wisconsin.

Most of the abstracts were written by the author after a reading of the original publication. Some, however, were drawn largely from *Forestry Abstracts* and the *Abstract Bulletin,* though with minor editorial changes, deletions, or amplifications. The author recognizes that limits of time and linguistic ability have probably caused omissions and misinterpretations.

For continuity and convenience to the reader, the author has attempted to duplicate the style and format of the previous paper (Koch 1968, Bibliographies). Each paper is abstracted under its major subject-matter category; the large categories are subdivided. To enhance utility, papers are cross-referenced in all pertinent categories. Cross-references take the form:

Doe. 1966. (Sawing; Bandsawing)

Such a reference indicates that the full citation appears in the Sawing category, under the subhead Bandsawing. The subject matter heads are summarized in the table of contents. An index of authors appears on page 34. In two categories—Grinding, and Machining with High-Energy Jets—no papers were located.

HIGHLIGHTS OF THE LITERATURE

The review indicates that research is continuing at a high level. About 66 publications per year appeared in archival journals for the years 1963 through 1965. *Wood Machining Abstracts, 1966 and 1967* (Koch 1968, Bibliographies) contained a total of 326 references with 138 titles from 1966 and 103 from 1967. The total number of references in the present review is 322. Of these, 187 are from 1968 and 89 from 1969. The remaining 47 articles were published prior to 1968 but not included in previous reviews. Probably the present review omits some publications that appeared late in 1969.

As in 1966 and 1967, sawing research led in activity with 47 papers listed (exclusive of cross-references). Of these, 11 dealt with circular sawing, 11 with sash gangsawing, and 9 with shearing.

Twenty-one papers reported field trials and experiments with chipping headrigs and edgers. As expected, industry is rapidly applying this laboratory-developed concept.

Defibrating of wood received great attention. The 33 papers cited here are in sharp contrast to the 8 reviewed during the 1966 and 1967 period. Veneer cutting was the subject of 39 papers (up from 19 papers in the 1966-1967 review).

Properties of the cutting edge and cutter also received considerable attention: 11 papers dealt with fitting and sharpening, 8 with dulling, and 5 with stability of the cutting edge. Twelve publications were devoted to the problems of safety and noise created by woodworking tools.

[1] The chief previous compilations:

ommittee on Recent Wood Machining Literature. **Wood machining abstracts, 1957-1958.** Forest Prod. Res. Soc., Madison, Wis. pp. 1959.

ommittee on Recent Wood Machining Literature. **Wood machining abstracts, 1958-1959.** Forest Prod. Res. Soc., Madison, Wis. pp. [1960.]

ommittee on Recent Wood Machining Literature. **Wood machining abstracts, 1959-1961.** Forest Prod. Res. Soc., Madison, Wis. pp. 1961.

och, P. **Wood Machining Processes.** 530 pp. N.Y.: Ronald Press Co. 1964.

och, P., and McMillin, C. W. **Wood machining review, 1963 through 1965.** Forest Prod. J. Part I, 16(9): 76-82, 107-115; Part II, (10): 43-48. 1966.

och, P. **Wood machining abstracts, 1966 and 1967.** USDA Forest Serv. Res. Pap. SO-34, 38 pp. South. Forest Exp. Sta., New leans, La. 1968.

General machinability of lumber and particleboard was discussed in 20 papers. Ten papers were devoted to barking, 11 to machining with coated abrasives, and 10 to research instrumentation and techniques. Thirteen papers discussed the history of wood machining or were of a general nature. The effects of wood properties on the machining process were considered in 7 papers.

Despite the obvious risk of offending researchers by omission or misinterpretation, it seems worthwhile to attempt some mention of individual contributions in various categories of endeavor.

History and general texts. — Brief histories of chain sawing were presented by McArthur (1969) and Penberthy (1968), and in two articles by unknown authors. Information useful in the design, maintenance, and operation of woodworking machinery was provided by Conzett (1969), Goodness and Dunn (1969), Minges (1969), and Schmutzler (1968). Kollmann and Côté (1968) reviewed the technology of wood machining in 56 pages of their 592-page book, *Principles of Wood Science and Technology.*

Properties of wood. — Kennedy (1968) discussed the influence of anatomical variables and density on the behavior of wood in transverse compression. McKenzie and Karpovich (1968) considered the coefficient of friction as it relates to wood machining. McMillin (1968) described the morphological characteristics and chemical composition of loblolly pine wood (as distinct from the properties of stems) in relation to its specific gravity, growth rate, and distance from the pith.

Orthogonal cutting. — Hayashi and Tochigi (1967, 1968) continue to explore the slow-speed orthogonal cutting of veneer. Keith and Côté (1968) described slip lines and compression failures that occur in wood cells of several softwood species during microtome sectioning. Stewart (1969) investigated the effect of grain angle on the quality of an orthogonally machined surface.

Peripheral milling. — Mori (1969) continued his studies of the planing process.

Barking. — Greaves (1968) developed information on the adhesion of bark to wood during debarking of steamed logs. Polozov (1967, 1969) described continued tests with a device that utilizes a mixture of compressed air and sawdust as the debarking agent. The technological and economic aspects of various debarkers and debarking plants were considered by Holzhey (1969).

Sawing. — Beck (1969) found that performance, working life, energy consumption, and surface quality were better for framesaw blades with swage-set tee hardened by high-frequency heating than for blades wi spring-set teeth coated with hard chromium. Fonk (1969) examined the relationship betwen kerf dep and framesaw stroke with special reference to the qu tion of sawdust removal when the stroke is less than t kerf depth. Thunell (1968) supplied diagrams a graphs showing the vertical and horizontal forces t develop in framesaws with stroke lengths of 600 a 700 mm.

Hallock (1968) presented design characteristics a performance data for a new circular saw with redu kerf. The saw is tapered in a compound manner, so t the board rubs the middle area of the plate. Thus, is stressed (tensioned) by heat generated during sawi

Carruthers (1968) described and illustrated a ch ping-saw for processing softwood logs into S4S ca Instead of sawdust, the saw makes chips suitable particleboard; the yield of sawn timber is the same that obtained from conventional saws.

Erickson (1967, 1968) and Johnston (1967, 19 investigated numerous aspects of crosscutting logs w shear blades. They concluded that shearing forces greater in frozen than in unfrozen logs, sharpness a has little effect on cutting force, cutting force increa with increasing wood specific gravity, increases in k thickness rapidly increase the shearing force, and a loading from the weight of a straight stem has l effect on force.

Jointing, planing, molding, and shaping.—A Ger finger-jointing system that can produce up to 66 jo per minute was described by Cook (1968). After joints have been machined, the boards are united continuous ribbon by a high-frequency glue-curing s tem and then cut to length.

Marian (1968) and Ivansson and Strom (19 also described cutters and other equipment for ma strong finger joints. The fingers are 7.5 mm. long tips 0.2 mm. wide. Application of high longitu pressure permits transportation and processing of joined pieces while the adhesive is setting.

Hobbs (undated) discussed the occurrence of marks and raised, fuzzy, or chipped grain in pla operations. He also reviewed the effects of such vari as knife cuts per inch, feed rate, cutterhead speed, c of cut, cutting angle, moisture content, and wood cific gravity on the quality of the finish.

Turning. — Rietz and Jenson (1968) gave d specifications for producing check-free turnings beech wood.

Boring, routing, and carving. — Chudnoff and ytia (1967) studied the spindle carving of several ical hardwoods. Generally, carvings machined from en wood had better surfaces than did carvings ma- ed from dry wood. Fuzzy grain was the principal ect in green carvings, while split-outs were most ous in dry carvings.

According to Kotesovec (1968), cylindrical holes be made in wood by thermal decomposition, with s that generate frictional heat.

For drilling standard hardboards, Priest (1968) mmended rotational speeds of 3,000 to 4,000 r.p.m. a drill point angle of 170°.

Machining with coated abrasives. — Buell and ens (1968) provided two schedules for sanding d-plastic combinations to a uniform, glossy finish. guson (1968) and Connolly (1969) discussed the ous functions of sanding in furniture finishing and ribed the backings, adhesives, and granules used in manufacture of coated abrasives. Pahlitzsch and er (1968) continued their basic research on machin- with coated abrasives.

Veneer cutting. — Cade and Choong (1969) re- ed that the tensile strength of southern pine veneer negatively correlated with cutting velocity and posi- y correlated with log diameter. Cumming et al. 69) examined the rotary cutting characteristics of g-growth redwood and gave recommendations for ing veneer equal in quality to that from old-growth ood. Feihl and Carroll (1969) disclosed the posi- advantages of rotary cutting with an air-actuated ing nosebar. Feihl (1967) traced the development oller-bars, discussed their maintenance, and com- d their performance with that of fixed bars.

Kacalin (1968) recommended that ash wood be ed to 113° F. prior to cutting, while Hailey et al. 68) recommended a 24-hour, 160° F. treatment for m fir. Kubinsky and Sochor (1968) softened us hardwoods in water at 266° F. and under pres- of 114 p.s.i.; under these conditions, treatment was reduced from 100 hours to 4 to 12 minutes.

Peters (1968), Peters and Zenk (1968), and Peters (1968, 1969) continued to report results on slic- hick veneer (thin lumber). They investigated mul- flitches and precompression of flitches, cutting ds, types of pressure bars, and degrees of pressure- compression and restraint.

Woodruff (1966) compared the bending strength eams made from slicewood cut at varying degrees recompression to the strength of beams made from laminae. Strength was independent of degree of precompression and knife angle but appeared to be lower for beams from slicewood than for those from sawn laminae.

Chipping, flaking, and grinding. — According to de Montmorency (1969) chip requirements are essentially the same for the kraft, sulphite, and refiner groundwood processes. The separation of bark from chips was discussed in papers by Benson and Peckham (1968), Einspahr et al. (1969), and Erickson (1968).

The power required to produce wood chips with an 18-inch, twin-disk chipper was measured by Papworth and Johnson (1968). Specific chipping energy increased with wood density. There was little difference in energy requirements between frozen and unfrozen wood. Horsepower consumption increased with log diameter.

Bryan (1969) and Shepard (1968) discussed a slabbing-chipper that is located just ahead of a band or circular headrig. The chipper removes a slab from the log while the saw makes the first lumber cut. Thus, it is possible to produce one board and pulpable chips in a single pass of the carriage. Numerous additional references dealt with field trials of chipping headrigs and with the general state of the art.

Cervenak (1967), Blumenstock (1968), and an anonymous author (1968) described a new mobile debarker-chipper powered by a gas-turbine engine. The unit is intended for chipping tree-length logs up to 22 inches in diameter at a rate of 120 lineal feet per minute; it is operated by one man and can chip 25 cords per hour.

Lutz et al. (1969) evaluated four methods of blanking softwood dimension lumber to produce flakes suitable for particleboard while simultaneously generating a smooth lumber surface.

Defibrating. — Allen et al. (1968) investigated the production of refiner groundwood from deciduous species while Braun and Davis (1969) studied the printability and strength properties of stone and refiner groundwood pulps from various softwood species.

The manufacture of refiner groundwood was the subject of reviews by Fuentes (1968) and Leask (1968), while Trevelyn (1969) reviewed all aspects of mechanical defibrating with particular emphasis on the southern pines.

Hatton (1968) demonstrated that 3 months' storage of lodgepole pine chips may substantially reduce brightness of refiner groundwood pulps. He recommended that chips be processed with a minimum of delay.

In a series of four papers, McMillin disclosed certain aspects of wood and pulp quality affecting the proper-

ties of handsheets made from loblolly pine refiner groundwood. He found (1968) that burst, tear, sheet density, and breaking length were increased by applying high refining energy and using fast-grown mature wood of relatively low specific gravity. Handsheet properties were also improved by using fiber refined from wood having long, slender tracheids with thick walls (1969). A theoretical stress analysis suggested that thick-walled cells of small outside diameter may fail by diagonal tension or parallel shear, depending on the fibril angle, while under torsional stress during refining. Such failures result in ribbon-like fragments which research elsewhere has shown to provide the coherence necessary for strength development in mechanical pulps. In contrast, thin-walled cells of small outside diameter fail by diagonal compression and yield few ribbons. The analysis also indicated that long fibers are more desirable than short fibers because of greater induced stresses and improved chances of axial alignment between the disks.

McMillin (1969) further demonstrated that the burst and tear strengths of handsheets made from chips of varying chemical composition decreased with increasing extractive content after the independent effects of fiber morphology were specified. Lastly, he (1969) examined the quality of refiner groundwood pulp as related to handsheet properties and gross wood characteristics.

The properties of fiberboards manufactured from loblolly pine refiner groundwood were also examined by McMillin (1968, 1969). For the refining conditions and formation procedure studied, and after allowance for the effect of board specific gravity, most properties were improved by using fiber refined from dense corewood (0 to 10 rings from the pith). This wood consists of short, slender tracheids having thin walls that flex easily and collapse readily. McMillin's analysis suggested that these fibers readily fail in bending while under stress induced by the pressing operation. Such bending failures create conditions favorable for hydrogen bonding, and thus improve board properties.

Properties of the cutting edge and cutter. — Barz (1967, 1968) and Chardin and Froidure (1967, 1968) continued their research on dulling of cutting edges. McKenzie and McCombe (1968) found that corrosive wear of veneer knives was minimized by holding the knife at a negative potential of 60 volts with respect to the pressure bar.

Barz and Munz (1968) reviewed a number of test methods for determining the set or state of stress (tension) in circular saws and described a machine to evaluate tension. Cumming and Gill (1968) discussed circular saw instability in relation to thermal gradients caused by energy dissipated in the cutting process a from frictional rubbing of the saw against the woo

The role of friction in wood cutting was revie by McKenzie (1967).

Research instrumentation and techniques. — He and Brooks (1968) described a portable shadow-cast apparatus for measuring vertical deformations on wo surfaces. Jarrett (1969) discussed the use of electro vibration analyzers to detect machine disorders. McK zie (1969) described a procedure for obtaining quar tative data on strains associated with penetration o cutting edge into wood, while Schmidt and Herb (1968) designed a photoelectric torsional dynamome for measuring the input power requirements of rotat machinery.

Safety, including noise. — Axelsson (1968) del eated the effects of vibrations on fingers and hands those who operate power saws and suggested tolera limits. Greenwood (1968) described an enclosure signed for reducing noise levels near planing and mo ing machines. Electrical grounding techniques were viewed by Klufas (1968), and Larson (1968) enum ated safety precautions for chain saws.

Wood machining in man's environment. — To author, present trends in wood machining have impl tions in two areas of considerable contemporary i terest: the need for improving the environment, and problem of deriving increasing amounts of wood f from a continually shrinking forest acreage.

Kerfless shears for felling trees and bucking are increasingly used in forestry, and further deve ements can be anticipated. They save fiber now lost s stumps are low and chain saw cuts are not requi Properly designed and operated, these machines well minimize damage to site ecology.

The most significant recent development in tim processing has been the widespread adoption of c ping headrigs. By eliminating much sawdust these chines remove one source of air pollution, since saw still has limited uses and is chiefly disposed of burning.

Researchers at the USDA Forest Products Labora continue development of a machine for kerfless cut of cants and logs into thin lumber. This process further increase the yield of merchantable solid w sawdust and its attendant disposal problems are avoi

The wood fiber industry appears ready to accep creased quantities of pulps made by mechanical m — that is, by stone grinding or by disk defibrators. pulps are potentially suited for a wide variety of p

cts. The processes increase recovery of fiber per ton f raw material, and thus have the effect of augmenting ıe timber supply. Since few or no chemicals are re-uired, and lignin and other soluble wood constituents e not removed, it appears that another source of water ıd air pollution may soon be reduced.

Other wood scientists have directed their attention ward man in relation to his working environment. Notably, considerable research is aimed at controlling the excessive level of noise associated with many types of woodworking equipment.

Thus, both the solid wood products industry and the fiber industry appear to have moved closer to complete utilization of the whole tree while effecting improvements in the environment in which man lives and works.

HISTORY AND GENERAL TEXTS

honymous. [n.d.] ALL ABOUT USING CHAIN SAWS. mark Ind., Inc., 25 pp. Portland, Oreg.
short history of chain saws and their fundamental uses, th directions for their selection, maintenance, and safe oper-ion.

honymous. 1967. THE HISTORY OF TIMBER SAWING. mark Ind., Inc., 6 pp. Portland, Oreg.
scribes and illustrates the development of chain saws from 58 to the present.

rdnikov, V. I. 1968. COMPRESSED AIR IN THE WOOD-RKING INDUSTRY. 232 pp. Moscow: Izdatel'stvo 'Lesnaja myslennost'.
book dealing with the basic statics and dynamics of using mpressed air. Also considered are main and ancillary equip-nt, calculations, planning, applications, economies, and fety.

hzett, J. C. 1969. DIAGNOSE THE HEALTH OF YOUR CHINE OR PROCESS WITH VIBRATION MEASUREMENT. Pp and Pap. 43(1): 108-109.
asurement of vibrations can be useful in detecting impend-ıl machine failure.

btree, D. E., and Davis, E. L. 1968. EXPERIMENTAL NUFACTURE OF WOODEN IMPLEMENTS WITH TOOLS OF KED STONE. Science 159: 426-428.
Sveral contemporary archeologists are recapturing the almost-lo art of knapping (shaping) stone artifacts by pressure and pussion. The authors describe three experiments in the coing of wood implements with stone tools alone, and out-li some problems of making and applying a lithic tool kit.

Erer, M., and Blasy, M. 1969. THE MODERN SAWMILL. I. MACHINERY OF THE SAWMILL. Holz als Roh- und Werk-stf 27: 125-147.
T first part of a general discussion of modern sawmilling ptice and equipment. Included is a survey of world forest rources and of the development of sawmill machinery. The mo important sawmill machines — debarkers, frame saws, bdsaws, circular saws, and machines for sharpening and maintaining sawblades — are individually described.

Gdness, B. F., and Dunn, T. E. 1969. POWER SYSTEMS: DI AND LIMITING AND LOAD-SHEDDING CONSIDERATIONS. TPPI 52: 848-852.
Dusses the aspects of demand limiting and load shedding in providing a reliable, continuous source of power for mill oprations. Equipment to perform these functions is described an methods of reducing power costs are given.

Hauffe. 1969. (Chipping, Flaking, and Grinding; Mobile Chippers)

Holzhey. 1969. (Barking)

Kollmann, F. F. P., and Côté, W. A., Jr. 1968. PRINCIPLES OF WOOD SCIENCE AND TECHOLOGY. I. SOLID WOOD. 592 pp. N.Y.: Springer-Verlag New York, Inc.
This book is primarily a reference for the wood scientist. Fifty-six pages are devoted to the technology of wood machining, including sawing; proposed methods of chipless cutting; jointing, planing, molding, and shaping; sanding; turning; tenoning and mortising; and boring.

McArthur, J. D. 1969. POWER CHAIN SAWS: THE FACTS AND THE FUTURE. Pulp and Pap. Mag. Can. 70(18): 55-57.
Briefly reviews the history and development of chain saws, and predicts at least a further 20 years of demand for them in Canada, despite the introduction of new methods of harvesting timber.

Minges, R. J. 1969. CONSIDERATIONS REQUIRED WHEN APPLYING THE NEW NEMA RE-RATE MOTORS (CA 4221). South. Pulp and Pap. Manufacturer 32(6): 77-82.
Discusses the recent National Electrical Manufacturers Association (NEMA) re-rate program for small and medium size alternating current motors and application of the new ratings in engineering design. The author explains why the changes were made and how they will affect motor characteristics. He enumerates precautions in applying the new re-rate motors, particularly in old systems used in conjunction with old motors.

Penberthy, R. J. 1968. ENGINEERING ASPECTS OF SAW CHAIN CUTTING. Proc., Forest Eng. Conf. ASAE Pub. PROC-368, pp. 44-46.
Traces the development of the saw chains of the early 1900's, which were of complex design and difficult to sharpen, to the more simplified and practical chains in use today. Discusses merits and functions of the now obsolete "scratcher type" and "chisel type" saw chains, analyzes recent innovations and improvements such as the "power-sharp chain," and evaluates the "chipper chains" of today.

Schmutzler, W. 1968. PROBLEMS IN THE CONSTRUCTION OF MODERN WOOD WORKING MACHINES. Holz als Roh- und Werkstoff 26: 237-243.
The interrelationships of speed, bearing load, fit, and lubrication are reviewed. Chip suction systems and causes and reduction of noise in woodworking machines are discussed.

Schmultzler, W. 1969. THE APPLICATION OF MATHEMATICAL SYSTEMS IN OPERATION PLANNING OF MACHINES. Holz als Roh- und Werkstoff 27: 337-343.

A mathematical model for estimating the relationship between available and required processing times.

Sointu, R. 1969. THE SAWMILLING INDUSTRY IN FINLA
Paperi ja Puu 51(1): 13-22.
Significant developments over the past 40 years include creased kiln-drying at the mill, mechanization in hand sawn goods, utilization of residues, and the use of data-pro ing machines.

PROPERTIES OF WOOD

Braun and Davis. 1969. (Defibrating)

Greaves, H. 1968. PRELIMINARY INVESTIGATION ON STEAM DEBARKING. CSIRO Australian Forest Prod. Newsletter 353, pp. 1-3.
Bark was more easily stripped when logs were steamed for 1 to 2½ hours than when not steamed. Microscopic examination showed that steaming disrupted the cells of the vascular cambium by degrading the structural pectin or causing differential rates of expansion between the lignified xylem and the phloem cells.

Keith and Côté. 1968. (Orthogonal Cutting)

Kennedy, R. W. 1968. WOOD IN TRANSVERSE COMPRESSION—INFLUENCE OF SOME ANATOMICAL VARIABLES AND DENSITY ON BEHAVIOR. Forest Prod. J. 18(3): 36-40.
Species studied were Douglas-fir, western redcedar, sugar pine, white oak, chestnut, beech, white elm, yellow birch, and black willow. Within a species, specimens loaded in a radial direction (load applied to a tangential face) generally were stronger than those loaded in a tangential direction. Stress at the proportional limit and modulus of elasticity were at minimum when rings were oriented 30° to 45° relative to the direction of loading. High ray volumes tended to lessen stress values when specimens were loaded on a radial face; when specimens were loaded on a tangential face, the proportional-limit stress increased although modulus of elasticity did not. The ratio between proportional-limit stress applied radially and applied tangentially increased with increasing ray volumes, and decreased with increasing latewood content and differential density within a growth ring.

McKenzie, W. M., and Karpovich, H. 1968. THE FRICTIONAL BEHAVIOUR OF WOOD. Wood Sci. and Technol. 2: 139-152.
Deviations from the classsical laws of friction were noted. Of particular significance was the variation in the friction coefficient with changes in sliding speed. On highly polished steel and with sliding speeds up to 4 m. per second, the coefficient undulated; but for unpolished surfaces a monotonic reduction in friction was observed, and was somewhat greater in wet wood than in dry wood. The coefficient was relatively unaffected by load, nominal contact area, and fiber direction. Results were explained in terms of adhesion and lubrication. From the wide selection of species tested, it appeared that the nature and amount of extractives in most woods cause them to have similar friction coefficients except on very smooth steel. A "greasy" species had significantly lower coefficients. For air-dry woods in contact with unpolished steel, the coeffi ranged from a static value of about 0.65 to a value of a 0.40 at 4 m. per second. For wet wood, the correspon values were about 0.70 and 0.15. Coefficients of friction tween two wood surfaces were similar to those between and rough steel. The coefficient between wood and materials varied in a manner which may have been relate strength of adhesion.

McMillin, C. W. 1968. CHEMICAL COMPOSITION OF LOLLY PINE WOOD AS RELATED TO SPECIFIC GRA GROWTH RATE, AND DISTANCE FROM PITH. Wood Sci. Technol. 2: 233-240.
The alpha-cellulose, hemicellulose, holocellulose, lignin, extractive contents of loblolly pine wood were independ related to specific gravity, rings from the pith, and gr rate. The results are unique in that they characterize chemical composition of wood as distinct from the che composition of stems.

McMillin, C. W. 1968. MORPHOLOGICAL CHARACTERI OF LOBLOLLY PINE WOOD AS RELATED TO SPECIFIC GRA GROWTH RATE, AND DISTANCE FROM PITH. Wood Sci. Technol. 2: 166-176.
Length and tranverse cellular dimensions were determine earlywood and latewood tracheids of wood removed from of loblolly pine and factorially segregated by specific gr rings from the pith, and growth rate. The independent tionships of each factor with fiber morphology are desc

McMillin. 1968. (Defibrating)

McMillin. 1969. (Defibrating)

Polcin, Wayman, Anderson, and Rapson. 1969. (Defibra

Schumann and Pillow. 1969. (Machinability of Lumbe Particleboard)

Sima, P. 1968. THE PHNOMENON OF FRICTION IN SL WOOD BY GRAVITY. Rev. Padurilor 83(1): 28-34.

Vasilev, J. K., and Narolin, V. I. 1968. STUDY OF FRICTION SURFACE OF COMPRESSED WOOD BY MEANS OF MICROHARDNESS METHOD. Les. Zh. 11(4): 79-82.
Presents data on the friction of compressed-wood compo on steel, with and without lubrication by silicon fluid or

ORTHOGONAL CUTTING

Hayashi, D., and Tochigi, T. 1967. EFFECTS OF NOSEBAR SHAPE IN VENEER CUTTING. I. FORCE ANALYSIS DURING THE ORTHOGONAL CUTTING PROCESS. Wood Ind. 22(12): 14-18.

Forces exerted on the nosebar were less on a nosebar land than on a conventional nosebar. The effect of land on forces increased as the horizontal nosebar opening dec

ecreasing the vertical opening increased forces, especially on bar having a land of 0.2 mm. The width of the land did ot affect cutting forces on the knife.

ayashi, D., and Tochigi, T. 1968. EFFECTS OF NOSEBAR HAPE IN VENEER CUTTING. II. EFFECTS OF THE LAND ON HE NOSEBAR ON LATHE CHECKS. Wood Ind. 23(1): 15-19.
nalyzes the depth, length, penetration angle, and spacing of the checks in relation to the amount of nosebar bevel or land. esults were best with a nosebar bevel of 0.5 mm., and vertical nd horizontal spacings between nosebar and knife of 95 and 0 to 40 percent of veneer thickness, respectively.

eith, C. T., and Côté, W. A., Jr. 1968. MICROSCOPIC HARACTERIZATION OF SLIP LINES AND COMPRESSION FAILRES IN WOOD CELL WALLS. Forest Prod. J. 18(3): 67-74.
eformations introduced during microtoming were investigated r several softwood species. It was concluded that the freuency of slip lines in radial sections was closely related to the e of the angle between the microtome knife edge and the ber direction. Slip lines were less frequent in unboiled than boiled blocks. The orientation of the slip lines was assoted with the positioning of the section with respect to the knife. Specimens of Japanese larch were loaded at the 1/3-points of a 9-inch span on the flat-grained surface nearest the bark and sectioned for microscopic examination. They showed compression lines only in the central span region; abundance of cell-wall deformations decreased from the compression to the tension side. There was an apparent relationship between locations of ray contact areas and bands of microscopic compression. Electron-microscope examination of carbon replicas of white pine showed (in surface view) cell-wall deformations as folds or wrinkles, and, in sectional views of the tangential cell walls of latewood tracheids, as zones of displacement of microfibrils.

Stewart, H. A. 1969. EFFECT OF CUTTING DIRECTION WITH RESPECT TO GRAIN ANGLE ON THE QUALITY OF MACHINED SURFACE, TOOL FORCE COMPONENTS, AND CUTTING FRICTION COEFFICIENT. Forest Prod. J. 19(3): 43-46.
Samples of white ash, one-quarter inch wide and conditioned to 7-percent moisture content, were orthogonally cut at varying grain inclinations from 90 - 0° to 90 - 90°. Cuts were made against and with the grain. The character and appearance of the surfaces are illustrated and compared to fluctuations in the normal and parallel tool force components.

PERIPHERAL MILLING PARALLEL TO GRAIN

ori, M. 1969. AN ANALYSIS OF CUTTING WORK IN PEPHERAL MILLING OF WOOD. I. ON THE WORK DONE BY KNIFE IN UP-MILLING PARALLEL TO WOOD GRAIN. J. Jap. ood Res. Soc. 15(3): 93-98.

Vasilevskaja, P. V., Ivanovskij, E. G., and Lautner, E. M. 1969. EFFECT OF THE ANGLE PARAMETERS OF THE CUTTER ON THE DYNAMIC AND ELECTRICAL CHARACTERISTICS OF THE CUTTING PROCESS. Derev. Prom. 18(3): 12-13.

BARKING

Anonymous. 1968. A FIRST AT WEYERHAEUSER: TURBINEFWERED MOBILE DEBARKER-CHIPPER GOES 50% FASTER. Fp and Pap. 42(45): 50.

Anonymous. 1968. (Chipping, Flaking, and Grinding; Mob Chippers)

Elson and Peckham. 1968. (Chipping, Flaking, and Grinding; Chipping)

Graves. 1968. (Properties of Wood)

Hzhey, G. 1969. MODERN DEBARKERS—THEIR TECHNOLOGIC AND ECONOMICAL ASPECTS. Holz als Roh- und Werkstf 27: 81-102.
Thnical and economic aspects of modern debarking machines a plants are discussed in detail.

Fao, J. 1968. TREE MONKEY GOES TO MARKET. Northern Loger 16(7): 18-19, 34-35.
Tmachine prunes straight trunks of either conifers or hardwds having diameters between 4 and 9 inches. Two men wi one machine can prune to a height of one log in about 3 inutes. The unit will cut limbs up to 2 inches in diameter.

Meev, A. 1968. THE EFFECT OF CERTAIN FACTORS ON SPIFIC RESISTANCE DURING THE BARKING OF LOGS. Can. D Forest. Transl. 273, 18 pp.

Mirencev, V. A. 1967. ANALYTICAL INVESTIGATION OF TH WORK OF ROTOR-TYPE BARKERS. Les. Zh. 10(3): 87-93.

Polozov, M. I. 1967. EXPERIMENTAL STUDIES ON THE PROCESS OF BARKING WOOD BY A JET OF COMPRESSED AIR WITH A SOLID (SAWDUST) FILLER. Les. Zh. 10(6): 71-75.
For jet pressures of up to 25 atmospheres, barking efficiency increased with increasing pressure. Optimum jet mixture was 99.5 to 99.3 percent air plus 0.5 to 0.7 percent sawdust, by volume. Lavals' nozzle was found to be the most efficient: the nozzle should be at an angle of 20 to 40° to the log with lengthwise mounting, or 30 to 40° with transverse mounting.

Polozov, M. I. 1969. EXPERIMENTAL PNEUMATIC BARKING INSTALLATION. Lesnaya Prom. (2): 11-12.
Describes the latest stage in the development of this experimental Soviet barker.

Vlasov, G. D., and Pokryskin, O. V. 1968. THE PRODUCTIVITY OF BARKING MACHINES. Derev. Prom. 17(10): 9-10.
Photographic time studies revealed ways of increasing the productivity of several rotor-type barkers.

Vyplel, K. 1969. ECONOMICS OF MACHINE BARKING. Holz-Zentralbl. 95(113): 1707-1708.

Zadorozynj, V. V., and Mireckij, V. O. 1968. BARKING WOOD WITH THE AID OF ELECTRIC CHARGES IN WATER. Lesnaya Prom. (11): 11-12.
A shock wave generated by a high-voltage electrical discharge in water was used to debark hardwood logs. Tests were made

on spruce, birch, aspen, and beech in the freshly felled, floated, dry, and frozen condition. Best results were obtained when the electrodes were installed parallel to the log and 10 to 15 mm. from it. Optimum electrical parameters were: capacitance 2 μf; voltage 35 to 50 kv. Barking quality was better for birch and aspen than for spruce. Good-quality barking was achieved on freshly felled, frozen, and dry hardwoods. Mechanically incising the bark in a longitudinal direction was ver helpful, especially with birch. With freshly felled wood, ele trical consumption (in kw.-hr. per cu. m.) was to 0.3 to 0.6 for birch and aspen, 0.5 to 0.7 for beech, and 0.8 to 1.3 fo spruce. With dry and frozen wood, consumption was greate reaching a maximum of 2 to 2.5 kw.-hr. per cu. m.

SAWING

GENERAL

Anonymous. 1968. (Properties of the Cutting Edge and Cutter; Fitting and Sharpening)

Anonymous. 1969. (Properties of the Cutting Edge and Cutter; Fitting and Sharpening)

Ask, W. 1968. TRAPEZOIDAL SAWING: POSSIBILITY OF SUBSTANTIAL INCREASE IN YIELD. Drevo 23: 364-367.

Axelsson. 1968. (Safety, Including Noise)

Bois, P. J. 1968. WEIGHT OF SAWDUST FROM SEVERAL SOUTHERN APPALACHIAN WOOD SPECIES. Forest Prod. J. 18(10): 52-54.
Tabulates the weight of sawdust of red oak, white pine, shortleaf pine, and red maple at various moisture contents. Three degrees of sawdust compaction are considered: lightly compacted, shaken, and densely packed.

Esterer and Blasy. 1969. (History and General Texts)

Kubler, H. 1968. SEMITUBULAR BOARDS . . . A NEW SAWING METHOD. Forest Prod. J. 18(5): 24-25.
A patented machine made by Schelling & Co., Schwarzach/Vorarlberg, Austria, employs a line of four hollow cylindrical saws of successively larger diameter to produce four half-cylindrical "boards" and a core from each half log. The manufacturer claims a higher lumber yield than with conventional saws, as no slabs or edgings are produced. Maximum capacity of the machine is 600 lineal feet per hour when sawing half-logs 7 inches in diameter. Aspects of drying the "boards" and their use in such products as corrugated panels for roofs and walls and tubular ducts are described.

Panasevic, T. G. 1968. IMPROVEMENT OF METHODS OF STUDYING WORK PROCESSES IN SAW-MILLING. Derev. Prom. 17(3): 1-3.

Tavoda, J. 1968. BAND SAWS OR FRAME SAWS FOR SAWING OF BEECH LOGS? Drevo 23(12): 402-405.
Compares the performance of the two types of saws and indicates factors to be considered in selecting suitable machines.

Thompson, W. S., and Darwin, W. N. 1968. WEIGHT, VOLUME AND MOISTURE CONTENT OF SAWDUST FROM SELECTED SOUTHERN SPECIES. Forest Prod. J. 18(9): 96.
Uniformly packed sawdust from freshly felled stems of green ash, cottonwood, baldcypress, soft elm, sugarberry, red and white oak, pecan, sweetgum, black willow, and yellow-poplar had an ovendry weight equal to about one-third that of ovendry solid wood.

Tsolakides. 1969. (Machinability of Lumber and Particleboard)

Yu, K. C. 1968. THE FRICTION SAWING OF WOOD. Forest Prod. J. 18(11): 65. *See also* M. Ap. Sc. Thesis. Univ. Brit. Columbia, Vancouver, B.C. 1966.
Friction sawing with a high-speed rotating disk was tested o Douglas-fir and western redcedar. A 14-inch-diameter, 1 gage steel disk with a smooth edge was driven at 4,620 r.p. Results showed that frictional forces, power consumption, a cutting temperature increased with feed speed. Moisture co tent had no noticeable influence on the cutting action. A n row kerf and straight, smooth, polished surfaces are so of the advantages of the process. Reasonably high feed spee were possible in cutting plywood and veneer. It is possib that friction sawing may be useful in cutting plastic shee A theoretical analysis of heat transmission characteristics a temperature distribution in the sawing disk is also present

BANDSAWING

Anonymous. 1968. (Research Instrumentation and Te niques)

Anonymous. 1968. EFFECT OF DEFECTIVE TEETH IN BA SAWING. Can. Dep. Forest. and Rural Develop. Res. Ne 11(1): 5.
White spruce, red pine, and yellow birch at moisture conte above 35 percent were ripped with a single-tooth cutting paratus. Feed speeds varied between 50 and 100 f.p.m. H angle was 35°, clearance angle was 10°, and kerf width ¼ inch. Defective teeth were simulated by grinding the to edge at an angle of 79° to the direction of cutting instead at the normal 90°. This change reduced the principal fo by 10 to 15 percent for white spruce and red pine, but indu lateral forces that about equalled the reduction in the princ force. For yellow birch, the reduction in principal force slightly less than 10 percent, while the induced lateral fo was between 10 and 15 percent of the original princ force. When a corner of the tooth was broken, a lateral fo as great as 35 percent of the principal force was measu It was concluded probable that successive broken corners teeth of bandsaws may cause lateral deflections of the b and lead to inaccuracies in sawing.

Anonymous. 1968. STENNER'S NEW DOUBLE BANDS Timber Trades J. 264(4774): 59-60.
This 36-inch, double bandsaw is particularly suitable for s softwood logs such as thinnings of 4 to 10 inches in dian and 5 to 20 feet in length. The chain and lug feed gear (to be patented) permits a high feed speed (150 f.p.m.) u the log is not in contact with the saw. When sawing, possible to automatically or manually select one of three speeds (25, 35, and 55 f.p.m.) It is claimed that, apart the saving of time achieved by making two cuts at one the percentage of time spent in actual sawing is more twice that of a conventional handmill.. The manufactu Stenner, Ltd., Tiverton, Devon, England, also plan a 48 model.

keland, R. 1967. INVESTIGATIONS ON SAWING ACCUCY FOR BIG BANDSAWS WHEN SAWING FROZEN AND UNOZEN LOGS WITH DIFFERENT FEED SPEEDS AND DIFFERT SWAGE SIZES. Norsk Skogindustri 21(7): 244-250.
sts were conducted on a vertical bandsaw having a 60-inch eel, blade thickness of 1.47 mm., and blade width of 230 n. For unfrozen logs of Picea abies, a saw velocity of m. per second was used for each of two tooth shapes. For zen logs, one tooth shape was tested and logs were cut a saw velocity of 35 m. per second. It was concluded that ving accuracy in unfrozen logs is independent of (or only ghtly dependent on) feed speed above certain values for age. For a tooth pitch of 1½ inches, the minimum swage s 2.5 mm.; for a tooth pitch of 2 inches, the minimum was 5 mm. Sawing accuracy is better for unfrozen than for zen logs. Frozen sawdust is less compressible within the llet than unfrozen sawdust.

rruthers, J. F. S., and Burridge, M. S. 1968. F.P.R.L. TOMATED RESAWING SYSTEM. Timber Trades J. 266-795): 49, 51.
prototype automated resaw system requiring only one oper-r has been designed by the Forest Products Research Lab-tory in England. The device, built around a 175-mm.-le bandsaw, provides (with further development) the first e in a completely automatic processing line which would ept sawn timber, cut it to size, and plane or mold it to required section. A diagrammatic layout is included.

Fktistov, A. E. 1969. SAWING ACCURACY AND PRODUCTITY OF BAND SAWS. Derev. Prom. 18(4): 12-13.

Kayama and Sugihara. 1968. (Safety, Including Noise)

Mntague, D. E. 1968. PRODUCTION RATES OF LOG BANDSWS FOR SMALL SOFTWOOD LOGS. Timber Trades J. Annu. Sc. Issue: S/1-S/3, S/35.
Cmpares production rates of five types of sawmills: (1) a 54-inh and 60-inch bandsaw mill with Norwegian "bathtub" carrie (Mills A-1 and A-2 respectively); (2) two 60-inch bandsa mills with pneumatically operated carriages (Mills B-1 an B-2); (3) a 43.2-inch single circular sawmill with "bathtu" carriage (Mill C); (4) a 43.2-inch single circular sawmi with rope-driven table and attached moving floor (Mill D and (5) a 43.2-inch double circular sawmill fed by a sog chain (Mill E). The circular mill with a "bathtub" carrie (Mill C) had a higher production rate than the bandsa mills with carriages of the same type (Mills A-1 and A-2), bu required an extra employee and was wasteful of material. Th circular double slabber (Mill E) also had a notably high pr uction rate. When only two slabbing cuts were taken, ba saws with "bathtub" carriages had a higher production rat for short logs than bandsaws with pneumatically operate carriages, but for long logs the difference was insignificant.

Shiks. 1968. (Properties of the Cutter and Cutting Edge; Fitng and Sharpening)

SASH GANGSAWING

Bapwski. 1968. (Properties of the Cutting Edge and Cutter Fitting and Sharpening)

Bet E. 1969. CUTTING CHARACTERISTICS OF FRAME-SAW BLES TREATED IN DIFFERENT WAYS. Holz-Zentralbl. 95(51): 749750.
In ill tests on spruce, performance, working life, energy consmption, and cutting quality were better for framesaw blades with swage-set teeth hardened by high-frequency heating than for blades with spring-set teeth coated with hard chromium.

Fischer, R. 1967. ANALYSIS OF DYNAMIC PROCESSES OF FRAME SAW MACHINES WITH LATCH SUPPORT. Holzindustrie 20(6): 161-164.

Fonkin, V. F. 1969. EFFECT OF THE RELATION BETWEEN KERF DEPTH AND FRAME-SAW STROKE ON THE CHOICE OF TOOTH PITCH. Derev. Prom. 18(7): 11-12.
Discusses sawdust removal when the stroke is less than the kerf depth, and recommends tooth pitches for such situations.

Ioffe, A. I. 1967. THE NATURE AND PARAMETERS OF AUTOMATIC FEED CONTROL IN A FRAME SAW. Les. Zh. 10(6): 142-145.
Presents an algorithm for the automatic regulation of log feed into a framesaw. The algorithm is based on four parameters: number of blades, tooth pitch, log diameter or cant height, and motor load.

Jelinek, T. 1967. RECORD CUTTING OUTPUT BY NEW FRAME-SAW EQUIPMENT: 100-120 CU.M./SHIFT CONVERTED INTO BOARDS. Holz-Kurier 22(36): 10-11; (37): 6.

Krutikov, N. S. 1968. DETERMINING THE OPTIMUM SPEED OF FEEDING CANTS INTO A FRAME SAW. Les. Zh. 11(2): 112-115.
A theoretical study in which formulae are developed to predict the optimum speed of feeding cants into a frame saw. The analysis is supplemented by investigations in a Russian frame sawmill.

Nguen, H. 1968. THE SURFACE QUALITY OF VIETNAM HARDWOODS SAWN BY FRAME SAWS. Derev. Prom. 17(10): 12-13.
Graphs the relationships of chip thickness, feed speed, depth of cut, tooth swaging, and wood moisture content and density on surface roughness for several species. Gives feeds per tooth that yield various surface-quality classes in each species.

Potjarkin, L. P. 1968. EXPERIMENTAL INVESTIGATION OF THE IRREGULARITY OF ROTATION OF THE CRANKSHAFT ON A FRAME SAW. Les. Zh. 11(4): 75-78.

Thunell, B. 1968. CUTTING FORCES IN FRAME SAWS WITH DIFFERENT LENGTHS OF STROKE. Medd. Svenska Traforskn-Inst. (Trateknik) 160B, 3 pp.
Diagrams and graphs show the vertical and horizontal forces in saws with stroke lengths of 600 and 700 mm.

Thunell, B. 1968. ON THE CHIP THICKNESS IN A FRAME SAW. Paperi ja Puu 50(3): 103-108.
In frame sawing, chip thicknesses (bite per tooth) should be constant for optimum cutting conditions. A geometric analysis shows how this can be accomplished by selecting tooth pitches appropriate for various log sizes and feed speeds.

Turusev, V. G. 1968. METHODS OF POSITIONING SAWLOGS FOR CONVEYOR FEED. Derev. Prom. 17(11): 10-11.
An illustrated technical description of a Soviet tilting feed mechanism for turning, centering, and feeding logs into a frame saw.

CIRCULAR SAWING

Anonymous. 1969. VERTICAL PANEL CUTTING SAW. Timber Trades J. 269(4842): 58.
An inexpensive new British machine (illustrated) is available in two sizes and is designed primarily to cut 8- by 4-foot and 12- by 6-foot sheets. It saves floor space because the material

can be positioned vertically irrespective of whether a vertical or horizontal cut is required. Large sheets are easily handled by one man. The machine is manufactured by N. McEwan and Co., Engine Bridge Works, Chapel Hill, Huddersfield, England.

Betts, H. 1969. EXTRA-THIN SAWS INCREASE LUMBER YIELD. Wood and Wood Prod. 74(8): 28-29.
Discusses the Thrasher Lumber Company's system of sawing lumber with thin circular saws. The saws are made of 0.062- or 0.075-inch steel plates and cut kerfs of 0.090 to 0.115 inch. The reduced kerf increases yield of finished lumber by 20 to 60 percent.

Bunimovic. 1969. (Properties of the Cutting Edge and Cutter; Fitting and Sharpening)

Carruthers, J. F. S. 1968. REVENUE FROM RESIDUE. Timber Trades J. 267(4808): 57, 59-60.
Describes and illustrates the prototype chipping-saw system developed at Princes Risborough for processing double-faced green softwood logs into S4S cants. Instead of sawdust, the machine produces chips suitable for particleboard, and does so without affecting the amount of sawn timber obtained from the log. Results were best when two pairs of saws (800 mm. or more in diameter) cutting in the direction of the feed were off-set mounted above and below the work. Further development may make this system suitable for resawing air-dry softwoods and hardwoods.

Cumming and Gill. 1968. (Properties of the Cutting Edge and Cutter; Temperature)

Danielsen, B. S. 1969. TRIPLE CHIP TOOTH STYLE SAWS. Timber Trades J. 269(4842): 55.
Recent advances in manufacturing and sharpening have reduced the cost of carbide-tipped triple-chip saws. These saws are now more widely in use. The tooth style has good wearability and is particularly effective on laminated materials. For example, the cut surfaces of double-faced laminates on chipboard were virtually chip-free. The blades have also been successfully used in sawing plastics, aluminum sheets, and other nonferrous metals.

Dem'janovskij, Pinezskij, and Terent'eva. 1968. (Properties of the Cutting Edge and Cutter; Fitting and Sharpening)

Fukui, H., and Kimura, S. 1968. FACE BEVEL ANGLE (θ_f) AND HOOK (β) OF CARBIDE TIPPED SAWS IN SAWING WOOD PARTICLE BOARD AND FIBER BOARD. Wood Ind. 23(3): 21-24.

Grube, Sanev, and Paskov. 1967. (Properties of the Cutting Edge and Cutter; Stability)

Grube, Sanev, and Paskov. 1968. (Properties of the Cutting Edge and Cutter; Stability)

Haidt. 1968. (Properties of the Cutting Edge and Cutter; Tool Material)

Hallock, H. 1968. "TAPER-TENSION" SAW . . . A NEW REDUCED KERF SAW. USDA Forest Serv. Res. Note FPL-0185, 14 pp. Forest Prod. Lab., Madison, Wis.
Presents design characteristics and performance data for a new circular saw that reduces kerf by about 3/32 inch when cutting pine cants into 4/4 boards. The saw is tapered in a compound manner, so that the board rubs the middle area of the plate (centered about 60 percent of the distance from eye to rim) rather than the saw center. Thus it is stressed (tensioned) by heat generated during sawing. Sawing accuracy approached that of a conventional 7- to 8-gage saw and was considerably better than a conventional narrow-kerf 10- to 11-gage saw.

Hallock, H. 1969. SAWING TO REDUCE WARP OF LODGEPOLE PINE STUDS. USDA Forest Serv. Res. Pap. FPL-102, 32 pp. Forest Prod. Lab., Madison, Wis.
To investigate the relation of five variables to warp, some 680 lodgepole pine logs with diameters of 6 to 12 inches were sawed into 2- by 4-inch studs. The variables were sawing method, position of the log in the tree, position of the stud in the log, rotational position of the log's cross-sectional eccentricity, and the presence of visible compression wood. Of the three sawing techniques employed, the FPL-improved scrag method proved slightly superior to the standard scrag method and both were substantially better than the conventional method in yield of quality studs. Studs from butt logs showed more bow and crook, but less twist than those from upper logs. When all forms of warp are considered, there was little difference between yields from butt and upper logs. Bow and crook were more severe in studs from the area near the center of the log than in those from the area near the bark. Twist appeared unrelated to position of the stud in the log. Log diameter affected the grade yield only when twist was considered. There appeared to be a relationship between the placement of the sawing pattern and the cross-sectional eccentricity. Placement of the eccentricity vertically generally resulted in less warp and produced more upper grade studs. The presence of visibly evident compression wood on one or both ends of the log showed only a very minor relationship to warp and raised the question of the validity of identifying compression wood solely by visual methods.

Kemov, A. S. 1968. CIRCULAR SAW WITH SPECIAL ENLARGED GULLETS. Timber Trades J. 266(4791): 59, 61. (Transl. from Derev. Prom. 17(5): 27-28)
Describes test of circular saws having four equally spaced enlarged gullets. The saws were 2.2 to 3.0 mm. in thickness and 400 to 700 mm. in diameter, and had 23, 32, and 4 teeth. The depth of the gullets was 15 percent of the blade diameter for saws 400 to 500 mm. in diameter and 2.2 to 2.6 mm. thick, and 20 percent of the blade diameter for saws over 600 mm. in diameter and 2.8 to 3.0 mm. thick. Advantages claimed over conventional saws include greater stability and machine output, reduced noise, and lower power requirements.

Kostrikov, P. V., and Grube, A. E. 1968. Riving knives on circular saws. Derev. Prom. 17(2): 8-10.

Meriluoto, J. 1968. PRECISION IN CROSS-CUTTING BIRCH BOLTS. Paperi ja Puu 50(4a): 187-190.
When birch veneer bolts were crosscut with a pendulum saw the length and thickness of the bolt did not affect sawing accuracy if the bolts were clear and straight. However, accuracy was reduced in crooked and knotty bolts.

Nakamura, G. 1969. SOME EXPERIMENTS ON CUTTING TORQUE AND FEED FORCE IN CIRCULAR SAWING. J. Jap. Wood Res. Soc. 15(1): 1-5.
The author gives equations relating cutting torque to rotational speed, feed force to rotational speed, and cutting torque to feed force. He also discusses the effects of workpiece thickness and blade projection on cutting torque and feed force.

Okushima, Sugihara, and Umemoto. 1969. (Properties of the Cutting Edge and Cutter; Temperature)

amaguchi. 1967. (Properties of the Cutting Edge and tter; Tool Material)

CHAIN SAWING

nonymous. [n.d.] (History and General Texts)

nonymous. 1967. (History and General Texts)

nonymous. 1969. POWER SAWS WITH HEATED HANDLES. olz-Zentralbl. 95(128): 1947.

iefly describes and illustrates the Swedish R18 chain saw. or cutting in cold weather its handles can be warmed to any sired temperature by passing exhaust gases through them. e warming is claimed to alleviate an occupational disease med "white fingers" that is associated with vibration com- ed with cold temperatures.

rson. 1968. (Safety, Including Noise)

Arthur. 1969. (History and General Texts)

berthy. 1968. (History and General Texts)

ensson, B. 1969. VIBRATIONS OCCURRING IN CHAIN-WS. Timber Trades J. 269(4831): 59.

erator comfort was improved and the risk of injury from ration reduced by insulating the front and rear handles m the saw engine with three rubber elements.

MACHINING WITH HIGH-ENERGY JETS

No articles found.

MACHINING WITH LIGHT

Waver, L. A. C., and Osial, T. A. 1969. CHANGING MATE-ILS WITH LASERS. Ind. Res. 11(8): 46-48.

ent improvements in their energy output, average power, reliability have increased the potential of lasers in manu- turing. Pulsed lasers, used for hole punching, drilling, and welding, have peak power levels in excess of 10^{12} w. pulse lengths approaching 1 psec., although power levels ween 100 kw. and 1 gw. and pulse lengths between 1 csec. 10 usec. are sufficient for most machining operations. gh-power continuous lasers, such as the CO^2 gas laser, pro- power in excess of 1,000 watts at greater than 10-percent iency and may be used for cutting metals or nonmetals as wood, ceramics, etc.

SHEARING

Anonymous. 1969. EFFECT OF FELLING WITH TREE SHEARS ON LUMBER LOSSES. Can. Dep. Fish. and Forest. Res. News 12(3): 8.

A preliminary report on the extent of damage to butt sections of trees cut with hydraulic shears. Approximately 115 lodgepole pine and white spruce stems having diameters from 6 to 14 inches d.b.h. were sheared at 45° F. and —25° F. Trim loss was greater when stems were cut at —25° F. than when cut at 45° F. Loss per tree increased with tree diameter in both samples; the greatest volume loss occurred with spruce cut at —25° F., while losses were least with spruce cut at 45° F.

Douglas, L. 1968. THE CAN CAR PROCESSOR. Northern Logger 17(3): 18.

The machine skids whole trees, delimbs them, and shears 8-foot bolts into a collecting basket.

Erickson, J. R. 1967. CROSSCUT SHEARING OF WOOD. *In* IUFRO Congr. Proc. 1967, Vol. 8, pp. 324-337. Munich.

The force (in pounds per inch width of cut) required to shear white spruce, aspen, eastern hemlock, yellow birch, and sugar maple was studied in relation to knife thickness, knife bevel angle, cutting speed, and dulling. Regression analysis yielded equations (containing single and multiple terms), that can be used to estimate the shearing force for each species tested. Knife thickness was the major factor: shearing force increased linearly with increasing knife thickness. Changing the thickness from ¼ to ½ inch increased force from 35 to 64 percent, depending on species. Bevel of the cutting edge (wedge angle) had no significant effect in hardwoods (aspen, birch, and maple), but in spruce and hemlock the force decreased with increasing bevel. Natural variations in moisture content or specific gravity affected the forces much less than knife thickness did. In hemlock, each 10-percent increase in moisture content above 30 percent caused a decrease of 18 pounds per inch width of cut. This effect was not observed in the other four species. Shearing force varied with specific gravity only in aspen and hemlock; the increase was approximately 40 pounds per inch width of cut for each 0.01 increase in specific gravity. Knife dulling had a pronounced effect; a 1/16-inch flat increased the force approximately 250 percent in spruce, 210 percent in aspen, and 130 percent in birch.

Erickson, J. R. 1968. CROSS-CUT SHEARING HARDWARE AND RESEARCH. South. Lumberman 217(2704): 111-114.

Discusses three types of shears for crosscutting timber—a single blade acting against an anvil, double blades acting against each other with a slight mismatch, and a delimbing type which does not act against an anvil but depends on the strength of the limb juncture to hold the limb in place while the cut is made. Splits, pullouts, and offsets are the most serious drawbacks in using shears. Blade thickness, wedge angle, match between the blade and anvil, single as compared to double blades, species, and wood temperature all affect the degree of damage to the log. Shearing force increases with knife thickness. For flat knives with a single bevel, shearing force decreases as the bevel angle increases from 20 to 45°; after 45°, the force increases. Force increases with increasing wood specific gravity. Frozen wood requires a greater shearing force than unfrozen wood.

Johnston, J. S. 1967. INVESTIGATIONS OF SOME VARIABLES IN THE CROSS CUTTING OF SMALL LOGS BY SHEAR BLADES. *In* IUFRO Congr. Proc. 1967, Vol. 8, Sect. 31-32, pp. 338-363. Munich.

From experience in cutting 3- to 6-inch spruce logs as well as accurately machined square specimens, the author concludes that:

1. *Cutting angle (wedge angle) of the shear blade has small effect on cutting force within the range of 25 to 45°.*
2. *Axial loading on the stem of a straight tree has little effect on cutting force, but a leaning tree may require considerably higher cutting force on the side under compressive stress.*
3. *A wide support, or anvil, increases force to cut with a single knife.*
4. *Cutting force increases with increasing specific gravity.*
5. *The amount of knife penetration at the point where maximum force is observed varies with the thickness and shape of the knife, and with the width of anvil.*
6. *Doubling knife thickness increases cutting force by about 50 percent.*

7. *Wood fails ahead of the knife edge in the manner of numerous small beams whose length is roughly double the knife thickness.*
8. *Total cutting force is composed essentially of a wedging component and a friction component.*
9. *The coefficient of friction for cutting green spruce under test conditions was 0.23.*

Johnston, J. S. 1968. AN EXPERIMENT IN SHEAR-BLADE CUTTING OF SMALL LOGS. Pulp and Pap. Mag. Can. 69(3): 77-82.
Reports on studies designed to reduce cutting forces, energy requirements, and wood damage when shearing short spruce (Picea glauca) logs. Logs having diameters as great as 6 inches were cut at about 3.3 inches per second. Three knife thicknesses (0.25, 0.39, 0.75 inch), three knife wedge angles (45°, 35°, and 25°), and two anvil widths (1 inch and 6 inches) were evaluated. In tests with two opposing knives, anvil width was considered to be zero. Axial loads were applied to the logs to simulate the weight of a standing stem. Knife wedge angle had little effect on cutting force in the range of 25° to 45°. Cutting force was least when two knives were used. Axial pressure had only a minor effect. White spruce, red pine, balsam fir, and jack pine were used in the study of knife thickness. Anvil width was 1 inch, and log diameters were about 4 to 5 inches. Cutting force increased with wood specific gravity. Increasing the thickness of the knife from 0.158 to 0.350 inch increased the cutting force by 50 percent. The amount of knife penetration at the point where maximum force was observed varied with the thickness and shape of the knife, and with width of the anvil. The coefficient of friction between the blade and green spruce was 0.23. Thus, it seemed unlikely that cutting force could be reduced significantly by lowering the friction coefficient.

Johnston, J. S. 1968. CROSSCUTTING TREES AND LOGS BY SHEAR BLADES. Can. Forest Ind. 88(6): 34-37. *Also in* South. Lumberman 217(2698): 39-41, 44, 46.
Reviews previous research on the effects of blade geometry and wood characteristics on cutting force, cutting energy, and wood damage. Summarizes investigations in Canada, Sweden, and the U.S., mostly in coniferous species.

Johnston, J. S. 1968. EXPERIMENTAL CROSSCUT SHEARING OF FROZEN WOOD. Proc., Forest Eng. Conf. ASAE Pub. PROC.-368, pp. 47-49, 55.
This study investigated the effect of moisture content, specific gravity, and other wood characteristics on cutting force and on damage to wood sheared at temperatures between 30 and —60° F. When 1-inch cross-sectional specimens of white spruce were sheared with a 0.10-inch-thick blade having a wedge angle of 45°, shearing force for both heartwood and sapwood increased with decreasing temperature. For all temperature, sapwood required greater force than heartwood, and the slope of the regression line relating temperature to force was greater for sapwood than for heartwood. In sapwood, but not in heartwood, forces were significantly higher for radial than for tangential cuts. Again in sapwood, damage (split length) increased as temperature decreased, and was greater for cuts in the radial than in the tangential direction. Temperature and cutting direction did not affect the length of splits in heartwood. Multiple regression analysis revealed that specific gravity had little effect on force, whereas moisture content had a strong effect below freezing. Shearing force increased with decreasing temperature; both the level and the slope of the relationship increased with increasing moisture content. Small logs of white spruce and balsam fir were also sheared with a 0.350-inch-thick blade with a 45° wedge angle. The force required to shear the log was interpreted in terms of the ratio of maximum cutting force to log diameter. Balsam fir logs required higher forces and were damaged more than spruce logs, seemingly because the fir logs had a higher moisture content. Shear force increased curvilinearly for balsam fir, reaching a maximum at about —30° F., then decreased. For spruce the relationship was linear. Maximum split length was a positive linear function of decreasing temperature for balsam fir. For spruce, split length decreased slightly with decreasing temperature to about 0° F., then increased.

Johnston, J. S. 1968. EXPERIMENTS IN CROSSCUTTING WOOD WITH SHEAR BLADES. Forest Prod. J. 18(3): 85-89.
Reports results of shearcutting 1-square-inch cross sections of white spruce (Picea glauca). *Doubling the thickness of the blade from 0.05 to 0.10 inch increased the cutting force about 50 percent. Force was only slightly greater when the blade wedge angle was small (22.5°) than when it was large (60°). Shearing forces were greater in the tangential than in the radial direction. In general, sapwood required a greater force than heartwood, and dull blades required greater force than sharp blades. Force was unaffected by moisture content above fiber saturation. When trees and logs are cut forces will probably be greater than for the 1-inch sections, because thicker blades are required and the surface area in contact with the wood is increased. The effect of blade thickness and wedge angle, however, probably will not be greatly different.*

JOINTING, PLANING, MOLDING, AND SHAPING

Bakiev, R. S. 1967. VIBRATION CUTTING OF WOOD. Les. Zh. 10(3): 108-110.
Examines the vibration cutting of wood purely from mechanical aspects, and concludes that cutting forces are reduced because of short-term periodic inertial forces that develop in the vibrating knife. Calculated values of cutting force as a function of vibration amplitude agreed very well with measured values.

Carruthers, J. F. S. 1968. DIE-FORMED END JOINTING. Woodworking Ind. 25(5): 19-20.
Lumber can be end-jointed by a process in which small fingers (3/16-inch long) are formed by forcing pieces of unheated wood against a metal die. Forming pressure is about 5,0 pounds per square inch. Adhesive is then applied and fingers are meshed under a thrust of about 2,500 pounds square inch. The adhesive sets in 8 hours at room temperature or may be cured in 20 seconds by high-frequency heating. The joint is about one-half as strong as clear wood in tension in bending. Although it is not quite as strong as a conventional finger joint, it appears adequate for joinery work where strength is not a major consideration. High wood moisture content at forming reduces strength of the joint, although maximum level of 20 percent is considered acceptable softwoods. Die-forming is feasible with most softwoods wh

densities are below 35 pounds per cubic foot. Above this level, it is necessary to pre-slit the wood.

Cook, A. J. 1968. HIGH-SPEED FINGER JOINTING. Timber Trades J. Annu. Spec. Issue: S/8-S/9.
Describes the operation of the German Dimter DFB/DKV high-speed finger-jointing system. Boards 10 inches to 23 feet long are sent by a continuous conveyor to shaping spindles which can produce up to 66 joints per minute (300 lineal f.p.m. outfeed). After joints have been machined, boards are united into a ribbon in a continuous press having a high-frequency glue curing system. They are then cut to the required length and may be transferred to molding lines or other machinery as required.

Hickler, H. H., and Helgesson, G. 1968. FINGER-JOINTING OF WOOD. III. MACHINE PROCESSING AND ECONOMIC ASPECTS OF A NEW FINGER-JOINTING METHOD. Holz als Roh- und Werkstoff 26: 157-161.
Describes the development of a special machine for making a new type of finger joint. Satisfactory joints were obtained in the laboratory and under industrial conditions. The cost of producing the new joint was half that of a conventional finger joint.

Greenwood. 1968. (Safety, Including Noise)

Hobbs, L. H. [n.d.] LUMBER MANUFACTURING DEFECTS IN THE PLANING MILL. N.C. State Univ. Wood Prod. Ext. Serv., 30 pp.
The occurrence of chip marks and of raised, fuzzy, and chipped grain are discussed in relation to such variables as knife cuts per inch, feed rate, cutterhead speed, depth of cut, cutting angle, moisture content, and specific gravity. The value of the summary is somewhat reduced by omission of numerous pertinent references.

Hansson, B. O., and Strom, H. 1968. FINGER-JOINTING OF WOOD. II. BASIC INVESTIGATIONS ON A NEW PROCEDURE OF FINGER-JOINTING. Holz als Roh- und Werkstoff 26: 77-84.
A new method produces finger joints of high initial strength. The fingers are 7.5 mm. long and the tips are 0.2 mm. wide. High longitudinal pressure on the joints permits transportation and processing before the adhesive has set completely. In ultimate strength, the joint is comparable to conventional joints, and a variety of adhesives appear suitable. The process has shown promise in limited industrial runs.

Kitayama and Sugihara. 1969. (Safety, Including Noise)

Lutz, Heebink, Panzer, and others. 1969. (Chipping, Flaking, and Grinding; Flaking)

Maldonado and Boone. 1968. (Machinability of Lumber and Particleboard)

Marian, J. E. 1968. WOOD FINGER-JOINTING. I. A NEW PROCEDURE FOR WOOD FINGER-JOINTING AND ITS PRINCIPLES. Holz als Roh- und Werkstoff 26: 41-45.
An analysis of conditions for an ideal end joint. A joint having very short (7.5 mm.) fingers is described, as well as the cutter required for its production.

Silina, G. E. 1968. AUTOMATIC REGULATION OF FEED SPEED IN FOUR-SIDE MOULDING MACHINES. Derev. Prom. 17(4): 10-11.
Discusses the need for, and gives an electrical diagram of, an automatic feed-speed regulating system.

Skljaeva, Z. A. 1968. PERFECTING MACHINE DESIGN SO AS TO IMPROVE THE WORKING CONDITIONS OF THE OPERATOR. Derev. Prom. 17(9): 12.
Suggests improvements in a spindle-molder, the object being to provide a stable position for the workpiece and optimize the height of the working surface.

Syrodaev, G. A., and Mel'nikov, A. V. 1968. INVESTIGATION OF THE PROCESS OF ROTARY CUTTING OF DENSIFIED (COMPRESSED) WOOD. Nauch. Tr. Lesoteh. Akad. 113, pp. 30-36.
Describes a series of experiments made on a modified thicknesser with natural and compressed pieces of birch and aspen. The compressed wood could be worked under conditions similar to those for hard species such as oak. Optimum knife angles were: rake angle 20°, sharpness angle 60°, and clearance angle 10°, for feed speeds of 8, 12, and 18 m. per minute and cutting depths of 1, 2, and 3 mm.

Vinogradov, V. A. 1966. IMBALANCE OF THE CUTTING TOOL OF A SPINDLE-MOULDER, AND THE MICROGEOMETRY OF THE MOULDED SURFACE. Les. Zh. 9(1): 94-99.

TURNING

Jetz, R. C., and Jenson, J. A. 1968. PRODUCING CHECK-FREE BEECH FOR TURNINGS. Forest Prod. J. 18(11): 42-44.
Rough-sawed and presurfaced 2½-inch squares and green rounds 2½ inches in diameter were kiln-dried to 8-percent moisture content on a schedule that caused surface checking in the rough-sawed squares. The pieces were 3 feet long. Presurfacing reduced checking from an average of 31.2 inches to 16.4 inches per square. Kiln-drying the rounds reduced surface checking to an average of 11.4 inches per specimen. The yield of acceptable turnings from the kiln-dried wood was 68.7 percent for the rough-sawed squares, 82.1 percent for the presurfaced squares, and 72.1 percent for the rounds. In the rounds, kiln-drying significantly reduced the amount of bow.

BORING, ROUTING, AND CARVING

Cudnoff, M., and Goytia, E. 1967. SPINDLE CARVING OF TROPICAL HARDWOODS. Turrialba 17(4): 430-435.
The spindle carving characteristics of 11 tropical hardwoods were empirically evaluated on specimens cut from stems measuring 15 to 22 inches in diameter at breast height. Samples for carving in the green condition were cut from the butt logs, while samples for carving dry were prepared by laminating defect-free, 1¼-inch air-dry boards (cut from the upper portions of logs) into blocks measuring 4½ by 5½ inches. The belt-driven, two-spindle carver operated at 11,000 r.p.m. A ¾-inch roughing cutter was used. After machining, the surfaces were evaluated for extent of fuzzy grain, chipped

grain, and splitouts. Generally, carvings machined from green wood had better surfaces than carvings from dry wood. Fuzzy grain was the principal defect in green carvings, while splitouts were most serious in dry carvings. Five species (guaraguao, roble blanco, laurel sabino, grandillo, and moca) produced a high percentage of acceptable carvings whether machined in the green or dry condition. No direct relationship was detected between the severity of interlocked grain and the quality of carved surfaces. For minimum drying degrade, ease of machining, and optimum response to treatment with polyethylene glycol-1,000, species having specific gravities less than 0.70 are recommended. Tests by other machining methods (for example, planing) do not necessarily indicate the spindle-carving characteristics of tropical hardwoods.

Kotesovec, V. 1968. WOODWORKING BY MEANS OF HEAT. Holztechnologie 9(4): 232-240.
Cylindrical holes were made with tools that operate by frictional heat. Tool shapes are described and the influence o tool shape, velocity, infeed power, hole atmosphere, specie temperature, and feed rate on torque is discussed. Power con sumption was higher than in conventional boring.

Priest, D. T. 1968. DRILLING TECHNIQUES FOR STANDARI HARDBOARD. Woodworking Ind. 25(10): 33-34.
When drilling hardboard, rotational speeds of 3,000 to 4,00 r.p.m. are essential if holes are to have true edges and raise fiber is to be avoided. However, if drill diameters are larg or feed rates are slow, lower speeds may be necessary to preven rapid blunting. The quality of the hole improves as th drill point angle is increased above the conventional angle o 118° to a value of 170°. Higher angles do not generally sho any significant improvement. The amount of raising varie considerably with the make of hardboard, but boards fro long fibers tend to be more difficult to machine than shor fiber boards.

MORTISING AND TENONING

Hyler, J. E. 1968. OVERLOOKED TRICKS ON DOUBLE-END TENONERS. Woodworking Dig. 70(8): 26-28.
Discusses the use of saw blades on double-end tenoners an on other double-end units.

MACHINING WITH COATED ABRASIVES

Anonymous. 1968. TAKING A SECOND LOOK AT ABRASIVE PLANING. Ind. Woodworking 20(9): 24.
Abrasive planers, designed to remove 3/64 to 1/8 inch and running continuously at 50 to 60 f.p.m., are capable of dimensioning workpieces close to tolerance without chipped grain, tearouts, or edgeband breakoffs.

Buell, H. W., and Stevens, S. F. 1968. ROUGH AND FINISH SANDING OF WOOD-PLASTIC COMBINATIONS WITH COATED ABRASIVES. Forest Prod. J. 18(11): 23-26.
Dry sanding was completely unsuccessful on red pine impregnated with methyl methacrylate and styrene acrylonitrile monomers and polymerized by gamma radiation and benzoyl peroxide. Satisfactory results were obtained with wet sanding, and two schedules are given for sanding wood-plastic combinations to a uniform, glossy finish.

Connolly, H. H. 1969. ABRASIVES AND CUTTING EFFICIENCY IN SANDING. Ind. Woodworking 21(7): 32-33.
Briefly discusses the functions of sanding in furniture finishing. The types of synthetic adhesives, backings, and abrasive grains (garnet, silicon carbide, and aluminum oxide) are considered as well as the effect of lignin flow at high temperatures.

Ferguson, J. S. 1968. WHAT YOU SHOULD KNOW ABOUT TODAY'S COATED ABRASIVES. I. Ind. Woodworking 20(6): 22-23, 28.
Briefly describes types of backings (paper, cloth, fiber, and combinations of cloth and paper), adhesives (glue, resin, and varnish), and abrasive grains (garnet, aluminum oxide, and silicon carbide) used in the manufacture of coated abrasives. Lists and explains product recommendations for drum sanders, multiple-drum endless bed sanders (including abrasive planers) and automatic turning sanders.

Ferguson, J. S. 1968. WHAT YOU SHOULD KNOW ABOUT TODAY'S COATED ABRASIVES. II. Ind. Woodworking 20(7): 14-15, 27.
Recommendations are given on various abrasive grains and products best suited to specific types of sanding equipmen

Jacjuk, A. I., and Popovic, V. V. 1967. MACHINE FOR SANI ING WOOD WITH ABRASIVE DISKS. Derev. Prom. 16(9): 8-
Describes the design of a disk sander used successfullly in se eral furniture factories in the U.S.S.R. Advantages claimed ov belt sanders include ability to sand workpieces after sawin lower costs, and improved productivity. The disks are 200 300 mm. in diameter, 100 mm. wide, and rotate at 1,590 r.p.

Manzos, F. M., and Gindin, M. N. 1967. SELECTION THE OPTIMUM LENGTH OF BELT CONTACT WITH THE WOR PIECE IN BELT SANDING. Derev. Prom. 16(9): 7-8.
Belt-contact lengths of 20 to 250 mm. were used with vario sanding speeds, contact pressures, and grit sizes. All belts all pressures exhibited a critical length of contact; exceedi this length did not increase sanding output at any speed. T critical length of contact was essentially independent of speci and only slightly dependent on contact pressure in the ran of 20 to 200 g. per square centimeter.

Pahlitzsch, G., and Meyer, H. R. 1968. ON THE SERVI LIFE OF SANDING BELTS DURING SANDING OF WOOD. Holz Roh- und Werkstoff 26: 441-447.

Potapov, B. 1967. TECHNICAL DOCUMENT: WIDE-BA SANDING MACHINES. Rev. Bois. Appl. 22(11): 10-37.
A technical description of the construction and operation various wide-band sanding machines.

Prokes, S. 1968. COMPARISON OF SOME TYPES OF SANDI BELTS. Drevo 23(12): 406-408.
Compares the properties and efficiency of recently develo Czechoslovakian belts with belts imported from East Germa

Schmutzler, W. 1967. THE APPLICATION OF WIDE-BE CONTACT SANDERS FOR VENEERED BOARDS. Holz als R und Werkstoff 25: 445-452.

VENEER CUTTING

nonymous. 1968. VENEER BLOCK HEATING. Borden Inc., hem. Div. Interim Rep. 17, 6 pp. N.Y.
lore southern plywood mills are heating veneer bolts before eeling. Most plants have conventional batch-type vats heated y steam or water but some have straight-line systems from he debarker to the lathe. The advantages and disadvantages f heating are enumerated and heating rates for bolts of various iameters and specific gravities are tabulated. Also included is table of vat capacities for batch-type systems.

nonymous. 1969. BACK GRINDING VENEER KNIVES. Can. ep. Fish. and Forest. Res. News 12(3): 1-2.

ade, J. C., and Choong, E. T. 1969. INFLUENCE OF CUTNG VELOCITY AND LOG DIAMETER ON THE TENSILE RENGTH OF VENEER ACROSS THE GRAIN. Forest Prod. J.)(7): 52-53.
pwood veneer strips were cut at speeds from 100 to 500 .m. from 24 southern pine bolts having diameters of 10 and inches. Specimens measuring 1 inch along the grain and inches perpendicular to the grain were prepared from the neer strips, equilibrated to an average moisture content of .2 percent, and measured for strength in tension across grain. Tensile strength was negatively correlated with ting velocity and positively correlated with log diameter. e interaction of log diameter and cutting velocity did not ve significant.

lson, T. C. 1968. ESTIMATING HOURLY PRODUCTION OF CED WOOD. Forest Prod. J. 18(11): 45-49.
es equations showing how slicing rate, loading delay, flitch dimensions, and product thickness influence input and output o a veneer slicer. The equations may be used in production nning and control, in feasibility studies, and in the design o new plants.

k, E. A. R. B. 1968. A NOTE ON SETTING THE KNIFE GLE FOR ROTARY VENEER PEELING. Malayan Forest. 31(3): 1-193.

Cming, J. D., Fischer, C., and Dickinson, F. E. 1969. RY VENEER CUTTING CHARACTERISTICS OF YOUNGGWTH REDWOOD. Forest Prod. J. 19(11): 26-30.
Veer is being rotary-cut from old-growth redwood, but us of young-growth redwood (60 years or less) has been limited. Seven variables (three levels of each) were investigated to determine their influence on veneer produced from young trees. The factors were growth rate, heating method, heating temperature, lead (vertical nosebar opening), gap (horizontal nosebar opening), clearance angle of knife, and nosebar type. Of all variables, only gap produced a significant difference (0.05 level) in uniformity of thickness. One standard deviation about the mean was ± 0.006 inch when the gap was 73 percent of the veneer thickness, and ± 0.004 inch when the gap was 83 and 93 percent of the thickness. Average veneer thickness was 0.141 inch. Too great a nosebar pressure caused excessive compression of the bolt, especially the softer parts (springwood overlying a band of summerwood). The three variables found to influence check depth were temperature, bolt diameter, and type of nosebar. Check depths averaged 1.05 inch at 140° F. and 0.054 inch at 160 and 180°. They averaged 0.051 inch for bolts 27 to 34 inches in diameter, 0.0 for 22- to 26-inch bolts, and 0.056 inch for 16- to 21-ch bolts. For the roller nosebar, check depth averaged 0.057 inch; for the fixed bar, the average was 0.052 inch. There was no significant difference between heating in steam and heating in water. The following conditions produced acceptable veneer:

Knife sharpness angle 20°
Knife height above lathe center 0.040 inch
Machine speed 50 r.p.m.
Gap 83 percent or 93 percent of veneer thickness
Clearance angle — ½° to + ½°
Lead 0.028 to 0.042 inch
Temperature at time of peel 160° to 180° F.

The author concludes that veneer of equal quality can be produced from redwood of either young or old growth.

Egusa, Y. 1967. CUTTING OF ROTARY VENEER. I. EFFECT OF POSITION OF NOSE-BAR TO KNIFE EDGE. (No. 1). *In* Forest Exp. Sta. Bull. 203, pp. 131-171. Meguro, Tokyo.

Feihl, A. O. 1967. Design and performance of roller pressure bars for veneer lathes. *In* IUFRO Congr. Proc. 1967, Vol. 9, Sect. 41, pp. 2-24. Munich. *Also as* Can. Dep. Forest and Rural Develop. Dep. Pub. 1225, 23 pp.
Reviews development of various types of roller bars, describes the bars and auxiliary equipment, discusses maintenance, adjustment, and cost, and compares performance of roller and fixed bars.

Feihl, A. O., and Carroll, M. N. 1969. ROTARY CUTTING VENEER WITH A FLOATING BAR. Forest Prod. J. 19(10): 28-32.
A study was made of veneer cutting with nosebars designed to apply a constant pressure against the log (floating). On a 4-foot laboratory lathe, very good veneer was obtained at pressures of 30 to 40 pounds per linear inch of log (p.l.i.) for a flat nosebar, and 50 to 60 p.l.i. for a motor-driven roller bar. Wide ranges of wood variables, veneer thicknesses, and cutting conditions in both softwoods and hardwoods were examined. There were no indications that nosebar pressure was strongly influenced by factors such as species, presence of knots, or veneer thickness. The floating bar was stable and little vibration was detected when peeling 1/10-inch Douglas-fir at 360 f.p.m. The bar was especially effective on highly figured wood. The effects of pressure were studied in detail when red pine was cut to 1/10 and 1/16 inch. The self-setting horizontal gap decreased slowly with increasing bar pressure, and the quality of veneer also changed. For both thicknesses a pressure of about 60 ± 10 p.l.i. gave good veneer. This study indicates that the concept of providing constant pressure with a floating nosebar is valid, and that a simple air-operated system is adequate.

Feihl, A. O., and Carroll, M. N. 1969. THE FLOATING BAR . . . A NEW APPROACH TO VENEER CUTTING. Forest Prod J. 19(4): 52.
The nosebar of a 4-foot lathe was modified so that it applied constant pressure against the log (i.e., was floating). On a lathe with no wear and play, the floating bar produced veneer equal in quality to that cut with a fixed bar. The proper cutting action therefore depends on the degree of compression and not on the means by which compression is obtained. Under mill conditions, however, it is difficult to maintain a fixed gap and hence it is expected that a floating bar will produce better

veneer. The floating bar also permits rapid adjustment of pressure while the lathe is running.

Feihl, A. O., and Godin, V. 1969. THE ROTARY CUTTING OF VENEER FROM NATURAL-GROWN RED PINE. Can. Dep. Fish. and Forest. Dep. Pub. 1254, 17 pp.
Nine 16-foot red pine logs, averaging about 14 inches in diameter at the butt and 12 inches at the top, were rotary-cut on a 4-foot lathe. Logs were peeled at temperatures ranging from 50 to 125° F. A fixed nosebar and a ⅝-inch motor-driven roller bar were tested. Results indicated that red pine can be cut without prior heat treatment when the knife has a microbevel. Heating the logs before peeling did not appreciably improve quality. When peeled with a fixed bar, logs sometimes jammed during the cut, and the chucks then chewed the log ends. The motor-driven roller bar greatly minimized these problems; veneer was similar in quality to that made with a fixed bar. The yield of veneer obtained from 4-foot bolts averaging 12.9 inches in diameter and peeled to an average core of 4.2 inches represented 67 percent of the bolt volume.

Godin. 1968. (Properties of the Cutting Edge and Cutter; Fitting and Sharpening)

Hailey, J. R. T., Hancock, W. V., and Walser, D. C. 1968. A PRELIMINARY STUDY OF THE EFFECTS OF HEATING ON THE PEEL QUALITY OF WESTERN BALSAM FIR VENEER. Can. Dep. Forest. and Rural Develop. Forest Prod. Lab. Inform. Rep. VP-X-34, 26 pp. Vancouver, B. C.
Sixteen bolts of western balsam fir were heated and cut on a 66- by 36-inch swing Cargate veneer lathe; eight bolts were peeled green at 70° F., five were heated in water at 160° F. for 24 hours, and three were heated for 42 hours. The smallest amount of substandard veneer (5.6 percent) was obtained with the 24-hour, 160° F. treatment. Cutting at 70° F. produced the greatest amount of substandard veneer (15.6 percent) and severely damaged the knife.

Hayashi, D., Tochigi, T., and Eguchi, K. 1969. EFFECTS OF MICROSHARPENING OF KNIVES IN VENEER CUTTING. J. Jap. Wood Res. Soc. 15(4): 146-153.

Hayashi, D., and Sugiyama, S. 1968. INVESTIGATIONS ON THE PRODUCTION OF VENEERS OF MOSOCHIKU *(Phyllostachys pubescens* MAZEL). Wood Ind. 23(10): 22-27.

Hayashi and Tochigi. 1967. (Orthogonal Cutting)

Hayashi and Tochigi. 1968. (Orthogonal Cutting)

Hoadley. 1968. (Research Instrumentation and Techniques)

Il'inskij, S. A., and Rudnik, M. S. 1969. EFFECT OF GEOMETRICAL INACCURACIES IN VENEER PEELERS ON THE ACCURACY OF PEELING. Derev. Prom. 18(9): 13-14.

Jain, N. C., Gupta, R. C., Dev, I., and Bagga, J. K. 1968. SLICING CHARACTERISTICS OF INDIAN TIMBERS. Holzforschung und Holzverwertung 20(3): 59-61.

Jain, N. C., Gupta, R. C., Tandon, R. C., and Bagga, J. K. 1968. PEELING CHARACTERISTICS OF INDIAN TIMBERS. IV. *Tectona grandis* (TEAK). Holzforschung und Holzverwertung 20(4): 76-79.
Veneer of optimum quality was obtained when logs were soaked for 16 hours at 55° C. and cut with a knife having an angle of 90.5 to 91.2°. Cutting speed had no significant effect.

Jain, N. C., Gupta, R. C., Tandon, R. C., and Dev, I. 196
PEELING CHARACTERISTICS OF INDIAN TIMBERS. III. *Calophy*
lum tomentosum. Holzforchung und Holzverwertung 20(2):
40-41.

Kacalin, N. V. 1968. THE OPTIMUM TEMPERATURE FO
ASH FLITCHES BEFORE SLICING FOR VENEER. Derev. Pro
17(6): 12-13.
Flitches were heated in an autoclave until they attained u
form temperatures in the range between 30 and 90° C. Vene
quality was satisfactory when the flitch temperature was 45°
at temperatures greater than 65° the surface was woolly; a
above 80° surface quality, uniformity of thickness, and tens
strength were impaired.

Koch, P., and Woodson, G. E. 1968. LAMINATING BUT
JOINTED, LOG-RUN SOUTHERN PINE VENEER INTO LO
BEAMS OF UNIFORM HIGH STRENGTH. Forest Prod. J. 18(10
45-51.
Twenty laminated beams were constructed of log-run, bu
jointed, loblolly pine veneers 1/6 inch thick and 100 inch
long. The beams were 18 inches deep, 2 inches wide, a
25 feet long. Veneers were arranged in the beams accordi
to their modulus of elasticity (MOE). The stiffest were pla
outermost, and the most limber in the center. The venee
which were cut on a lathe, ranged in MOE from 510,000
2,960,000 p.s.i. and averaged 1,690,000 p.s.i. This aver
was 110,000 p.s.i. lower than the accepted species avera
The beams had an average effective MOE of 2,110,000 p
Average modulus of rupture was 9,020 p.s.i. with a 95-p
cent exclusion limit of 7,170 p.s.i., thus justifying an all
able stress in bending of 3,370 p.s.i. A single beam
structed on the same principle but made from veneers selec
to simulate log-run slash pine had on MOE of 2,400,
p.s.i. and an MOR of 10,080 p.s.i. The three butt joints
each lamina did not seriously reduce beam MOE.

Kubinsky, E., and Sochor, M. 1968. NEW SOFTEN
TREATMENT FOR BEECH LOGS BEFORE ROTARY PEELING
VENEERS. Forest Prod. J. 18(3): 19-21.
Thermal softening of veneer logs was improved by utili
the ability of porous hardwood (especially red beech) to
duct liquids in the fiber direction. Bolts were sealed on
end with a perforated disk and placed in a pressure ve
Hot water (130° C.) was then pumped into the vessel
pressure of 114 p.s.i. Under these conditions, treating
was reduced from 100 hours to 4 to 12 minutes. The
perature gradient across the log diameter was also diminis
Logs treated by the process produced light-colored venee
good tensile strength, and the tendency to form marginal s
during drying was slight. The process was most effective
freshly cut, sound, beech sapwood.

Kulikov, V. A. 1968. ERRORS IN THE THICKNESS
PEELED VENEER. Nauch. Tr. Lesoteh. Akad. 106, pp.
An analysis of the causes of variation in veneer thickness
ing peeling.

Ljuboslavskij. 1967. (Research Instrumentation and
niques)

Lutz, J. F., Mergen, A. F., and Panzer, H. R. 1969.
TROL OF VENEER THICKNESS DURING ROTARY CUTTING.
est Prod. J. 19(12): 21-28.
A study showed that a major cause of thickness variati
rotary-cut veneer is a reversal of the forces between the
carriage and the wood, depending on whether or not the

ure bar is contacting the wood. At the start of peeling and vhen the bar is opened during cutting, as for clearing splinters, he knife carriage and the wood bolt are pulled together. In ontrast, when the pressure bar is contacting the bolt, the nife carriage and wood bolt are forced apart. Uniformity of eneer thickness can be improved by eliminating play in the athe, keeping the pressure bar shut during round-up and broughout the cutting, using low nosebar pressure, and pre-oading the knife carriage against the wood bolt.

fcKenzie and McCombe. 1968. (Properties of the Cutting dge and Cutter; Dulling)

Tiheev, I. I. 1969. INCREASING THE PRODUCTIVITY OF ORIZONTAL VENEER SLICERS. Derev. Prom. 18(4): 4-6.
)escribes the development, in the U.S.S.R., of an automatic kkeoff and stacking device that removes veneers as they are liced from the flitch and stacks them in sets of correct order.

Tiheev, I. I., Plahov, V. N., et al. 1968. EFFECT OF SHEARING ONES ON THE QUANTITATIVE YIELD OF SLICED VENEER. erev. Prom. 17(4): 3-5.

alka, L. C. 1968. A SIMPLE FORMULA FOR PREDICTING ENEER LATHE SETTINGS. Can. Dep. Fish. Bimo. Res. Notes 4(4): 33.
n equation is developed to describe horizontal and vertical osebar openings as a function of veneer thickness, roller-bar iameter, knife bevel, wood species, wood-moisture content, d cutting temperature. The equation implies that optimum rizontal compression should increase with decreasing veneer ickness and roller-bar diameter and with increasing vertical ening and effective bevel angle.

lepelin, V. M., and Orlov, A. T. 1967. A mechanized owline for hydrothermal treatment of veneer logs. Derev. om. 16(7): 4-7.
mpares the economics of preparing veneer logs for peeling : (a) soaking loose logs in open tanks with water at 80 to ° C.; (b) heating bundled or containerized logs in closed nks with water at 80 to 95° C.; and (c) treating bundled containerized logs in open tanks with water at 30 to 40° C. design of a continuous line for treating by method c is scribed.

rry, D. A., Choong, E. T., and Fogg, P. J. 1968. SOME SERVATIONS ON THE INFLUENCE OF LATHE CHECK ORIEN-TION ON BONDING STRENGTH OF SOUTHERN PINE PLY-OOD. La. Agr. Exp. Sta. LSU Wood Util. Notes 14, 2 pp.
e-eighth-inch southern pine veneers 12 inches square and 5-percent moisture content were bonded with a phenol rmaldehyde adhesive (Cascophen W-163 resin) into 1,300 ywood panels. Closed assembly time varied from 6 to 60 inutes and panels were pressed at about 200 p.s.i. and 0° C. After pressing, panels were allowed to postcure for hours in an oven maintained at 105° C. Shear specimens re prepared from each panel. Specimens from half of the nel were kerfed so that lathe checks were pulled open; remaining half were kerfed so that checks were pulled osed. The resulting 6,500 samples were tested in accordance th U. S. Commercial Standard P-1-66. The average shear ength and percent wood failure were respectively 31.0 and 3 percent higher for samples pulled closed than for sam-s pulled open. It was concluded that differences in glue nd quality due to lathe check orientation are sufficiently at to affect performance criteria.

Peters, C. C. 1968. MULTIPLE-FLITCH METHOD FOR THICK SLICING. Forest Prod. J. 18(9): 82-83.
Continuous or multiple-flitch cutting minimizes problems associated with knife entrance and exit. The technique is recommended for consideration in the design of a protoype machine for slicing thick veneer.

Peters, C. C. Mergen, A. F., and Panzer, H. R. 1969. EFFECT OF CUTTING SPEED DURING THICK SLICING OF WOOD. Forest Prod. J. 19(11): 37-42.
One half and one-inch-thick specimens of red oak, southern pine, and yellow-poplar were cut at 190° F. on a specially designed machine. The knife had a 20° wedge angle. The pressure bar was conventional, having a 15° front-bevel angle with restraint. Cutting speeds were 5, 50, 200, and 500 f.p.m. The depth of knife-side fractures increased rapidly (approximately doubled) as speed increased from 5 to 500 f.p.m., especially in the range of 5 to 50 f.p.m. Depths (expressed as a percentage of veneer thickeness) ranged from 32 percent for ½-inch red oak and yellow-poplar cut at 5 f.p.m. to 82 percent for 1-inch southern pine cut at 500 f.p.m. Uniformity of thickness was not related to cutting speed or to wood species. The average variation in thickness (within a slice) was 0.016 for ½-inch slices and 0.031 inch for 1-inch slices. Maximum parallel and perpendicular knife forces were 291 and 454 pounds per inch of length respectively; on the bar they were 239 and 858 pounds per inch of length. Net cutting power ranged from 0.03 to 8.01 hp. per inch of length.

Peters, C. C., Mergen, A. F., and Panzer, H. R. 1969. SLICING WOOD ONE-INCH THICK: FOUR TYPES OF PRESSURE BARS. Forest Prod. J. 19(7): 47-52.
One-inch-thick slices of red oak, Douglas-fir, and bigtooth aspen were cut with four types of pressure bars—a conventional fixed bar with a 15° angle, a 15° conventional bar with restraint, a 1¼-inch-diameter free-rolling bar, and 1¼-inch-diameter bar overdriven by 10 percent. Cutting was done at 200° F. on a modified metal milling machine equipped with a 21° knife. Judged by depth of fractures and uniformity of thickness, the conventional-with-restraint bar set at low compression (0.1 inch) and high restraint levels (0.0 inch lead) generally performed best. The curvature of the slices produced with the conventional and the conventional-with-restraint bars was only about half that of the slices made with the roller bars. Maximum knife forces parallel and perpendicular to the cutting direction were 360 and 429 pounds per inch of length, while for the bar they were 280 and 725 pounds per inch.

Peters, C. C., and Zenk, R. R. 1968. EFFECT OF PRECOMPRESSION ON SLICED WOOD ½ AND 1 INCH IN THICKNESS. USDA Forest Serv. Res. Note FPL-0194, 6 pp. Forest Prod. Lab., Madison, Wis.
Precompressed and control flitches of chestnut oak and Douglas-fir were sliced ½ and 1 inch thick on a modified milling machine with a 1¼-inch-diameter roller pressure bar. Slicing was done at 70° and 200° F. and at two levels of compression and restraint. Precompression up to 40 percent of block thickness for Douglas-fir and 30 percent for chestnut oak blocks had little effect on the depth of knife checks and on variations in thickness of the sliced piece. However, precompression did reduce forces perpendicular to the cutting direction (as high as 4,187 pounds per inch for chestnut oak) as much as one-half. Increasing compression with a roller bar caused large increases in forces for both precompressed and control specimens.

Peters, C. C. Zenk, R. R., and Mergen, A. F. 1968. EFFECTS OF ROLLER-BAR COMPRESSION AND RESTRAINT IN SLICING WOOD 1-INCH THICK. Forest Prod. J. 18(1): 75-80.
One-inch-thick slices of clear flat-grained chestnut oak, Douglas-fir, and yellow-poplar were cut at 5 f.p.m. on a modified milling machine. Cutting was done at 70 and 200° F., with various amounts of compression and restraint applied by a free-rolling pressure bar 1¼ inches in diameter. In all cases, hot cutting was better than cold. Yellow-poplar cut much better than the other two species and was the only species that could be sliced without any physical damage. As compression increased, check depth generally decreased on the knife side and increased on the bar side. Increasing restraint had less effect than compression; it generally reduced the depth of checks on the knife side but had little effect on the bar side. Thickness variation, which ranged from 0.005 to 0.190 inch, was increased by increasing compression, while restraint had little effect. The best pieces were relatively smooth, with checks from 0 to ½-inch deep, and were cupped toward the pressure-bar side of the slice. Total forces ran as high as 2,180 pounds per inch of length.

Salehuddin, A. B. M., and Barefoot, A. C. 1968. STATISTICAL QUALITY CONTROL AND VENEERING RESEARCH ON SEMUL. Forest Prod. J. 18(2): 40-44.
Discusses the importance of using Shewhart's $\overline{X}$ and R charts for selecting proper peeling conditions, and tentatively recommends knife angles, vertical and horizontal nosebar openings, and wood temperatures for peeling good-quality semul (Salmalia malabarica) *veneers 1/32, 1/16, and 3/32 inch thick.*

Sevcenko, V. A., and Oniscenko, Z. A. 1968. RATIONAL UTILIZATION OF RAW MATERIAL IN THE PRODUCTION OF SLICED VENEER. Derev. Prom. 17(8): 23-24.
Tabulates schedules for steaming flitches of diffuse-porous woods (beech, maple, walnut) in conventional pits and autoclaves. Also makes recommendations for slicing and drying the veneers.

Simonov, A. S. 1968. INCREASING THE SURFACE QUALITY AND STRENGTH OF SLICED VENEER. Derev. Prom. 17(1): 12-14.
Tests were made to determine the effect of the degree of veneer compression (0 to 30 percent) and rake angle (90-70° during the slicing of oak, larch, birch, and aspen. The be rake angle was 80°. Optimum compressions for oak, birc and aspen were 10 percent for veneer 0.6 mm. thick, 15 pe cent for 0.8 mm. veneer, and 20 percent for 1.0 mm. venee For larch, optimum compressions were 7, 10, and 15 percen respectively.

Stegmann, G., Bismarck, C., and May, H. A. 1968. TH EFFECT OF MECHANICAL STRETCHING ON BEECH VENEER AND PROPERTIES OF PLYWOOD MADE THEREFROM. Hol Zentralbl. 94(9): 102-106.

Sulepov, I. A. 1968. EFFECT OF CERTAIN FACTORS OF TH PEELING REGIME ON THE VENEER QUALITY. Derev. Pror 17(3): 8.
A study was made of pressure-bar lead (—0.2 to 0.5 mm. radius of rounding (0.02 to 0.3 mm.), and angle (3 to 34° on veneer quality in peeling birch. Compression was he constant at 20 percent of veneer thickness. Optimum settin were: pressure-bar lead 0.1 to 0.2 mm., radius of roundin 0.1 mm., and pressure-bar angle 5 to 10°.

Woodruff, D. V. 1966. THE EFFECT OF PERPENDICULA PRECOMPRESSION OF FLITCHES ON THE BENDING PROPERTI OF HORIZONTALLY CUT SLICEWOOD. M.S. Thesis. Pen State Univ., University Park.
Fourteen yellow-poplar flitches from one tree were sliced a sawn into 280 laminae approximately ¼ by 2 inches cross section and 15 inches along the grain. Prior to conve sion, each flitch was precompressed perpendicular to the gra at pressures varying from 0 to 750 p.s.i. Each flitch was th cut into 20 laminae; 10 were horizontally sliced with a kni having either a 21- or 10-° sharpness angle, and 10 we sawn. Each was ripped in half; one-half was tested in bendi and the remaining half used to construct laminated bean Static bending tests revealed that strength values were lou for beams from sliced laminae than for those from sa laminae, but strengths were independent of degree of p compression and knife angle. Beams with sliced lamin oriented vertically to the load had strength values at le 80 percent as high as beams from horizontally placed sa laminae.

CHIPPING, FLAKING, AND GRINDING

CHIPPING

Benson, M. K., and Peckham, J. R. 1968. PRELIMINARY OBSERVATIONS ON A BARK AND WOOD CHIP SEPARATION PROCEDURE FOR ASPEN. Inst. Pap. Chem. Genet. Physiol. Notes 2, 8 pp.
After stems of 10- and 30-year-old aspen were chipped, separation of wood and bark by water flotation yielded data on whole-tree bark percentages, bark and wood densities, and seasonal variation in moisture contents of bark and wood. The flotation technique appears suitable for separating bark and chips from aspen of all ages.

Birjukov, M. V., Seljapin, F. N., and Petri, V. N. 1968. THE PREPARATION OF PULP CHIPS FROM LARCH IN MULTI-KNIFE CHIPPERS. Bumazhnaya Prom. (5): 19-20.
Presents results (in graphs) of a study on chipping 884 larch logs having diameters of 8 to 51 cm. The chipper was an Ottersland 550, and various combinations of knife projection (11.5 to 13.5 mm.) and sharpness angle (35 to 41°) w tested. A setting of 12.5 mm. and 41° gave few fines a a high percentage of standard chips. With other settin the percentage of fines was higher and varied with log dia eter. Frozen wood gave more fines and splinters than unfrozen wood.

Bryan, R. W. 1969. PORTABLE CHIP MILL USED AS PI MANENT UNIT IN TSI WORK. Forest Ind. 96(11): 86-87.
A Morbark Model 2240 Chiparvester was installed as a p manent chipping mill to utilize cull and small hardwoo (largely oaks) that formerly were girdled or sprayed as p of a timber stand improvement program. The objective to market material that previously had cost $7 to $12 per a to remove. Production averaged 200 tons or four gond cars per 9-hour day. The average diameter of material chip was 9 inches. A major modification in the Chiparvester the addition of a four-chain, 20-foot-long infeed deck.

Oregon chain cutoff saw was installed behind the debarker o buck crooked logs. Other additions included an elevated ll-weather cab for the operator, a chip screen, surge bin, and ar feeder.

Burchill, J. G. 1969. THE FUTURE OF CHIPS. Pulp and Pap. Mag. Can. 70(6): 88-89.
Brief narrative of chip production in Canada, including comments on inflationary pressures experienced by the Canadian umber industry.

Einsphar, D. W., Benson, M. K., and Peckham, J. R. 1969. OBSERVATIONS ON A BARK AND WOOD CHIP SEPARATION PROCEDURE FOR ASPEN. Forest Prod. J. 19(7): 33-36.
A sink-float bark-wood separation system for aspen chips is lescribed. Juvenile (9 to 10 years) and mature (30 years) tems were cut at various times of the year and the chips were orted by the system. Roundwood from 30-year-old trees stored or 6 months was also processed. During a substantial part f the year the mechanical action of the chipper broke enough ark-wood bonds so that separation in a single pass through well-designed flotation chamber appeared feasible. In months hen the cambium was entirely dormant, a secondary operation volving drying and reprocessing the rejects increased total ood recovery. Storing winter-cut wood increased the effecveness of the first separation. Observations indicate that he system works equally well for aspen of all ages.

Erickson, J. R. 1968. BARK SEPARATION DURING CHIPPING WITH A PARALLEL KNIFE CHIPPER. USDA Forest Serv. Res. Note NC-54, 3 pp. N. Cent. Forest. Exp. Sta., St. Paul, Minn.
Winter-cut logs of hard maple, soft maple, eastern hemlock, quaking aspen, and spruce were processed with a parallel-knife chipper. Chips from frozen wood had a higher percentage of free wood, bark, and fines, and a lower percentage of bark bonded to wood, than chips from unfrozen wood. Most chips were retained on screen with an 0.50-inch mesh, except that for hemlock more than 50 percent of the chips from both frozen and unfrozen logs were retained on a 0.25-inch screen. For all species except spruce, 51 to 89 percent of the bark separated from the wood during chipping.

Foblokiz. 1968. (Defibrating)

Ismaki, O. 1969. STUDIES ON THE PREPARATION OF CHIPS FROM END TRIMMINGS AND STICKS. Paperi ja Puu 51(4): 369-372.

Montmorency, W. H. de. 1969. WOOD CHIPS FOR THE CHEMICAL AND MECHANICAL PULP PROCESSES. Pulp and Pap. Mag. Can. 70(6): 85-86.
Chip requirements are essentially the same for the kraft, sulfite, and refiner groundwood processes. Chips should be uniform in moisture content, size and shape, and specific gravity. They should be moist and free from compression damage and bark.

Peyworth, R. L., and Johnson, K. R. 1968. POWER REQUIREMENTS FOR PRODUCING WOOD CHIPS WITH A PARALLEL KNIFE CHIPPER. Forest Prod. J. 18(10): 42-44.
Power consumption was measured for an 18-inch Soderhamn Haro parallel-knife chipper (V-belt driven at 200 r.p.m. by a 75-hp. motor). Species tested were hard maple, spruce, soft maple, aspen, and hemlock. Logs varied from 4 to 12 inches in diameter and were chipped in both the frozen and unfrozen condition. Chips were 1¼ inches long by ¼ inch thick. Specific chipping energy increased with wood density, but did not differ between frozen and unfrozen wood. Horsepower consumption increased with increasing log diameter and could be accurately predicted. The parallel-knife chipper required significantly less specific energy than did a disk-type chipper previously tested on the same species. Because its power consumption is low, operating costs and machine size are reduced. The parallel-knife machine should therefore prove useful at remote sites.

Pease. 1969. (Machinability of Lumber and Particleboard)

Youngblood, C. H., Klein, E. L., and Hopkins, W. C. 1967. THE FEASIBILITY OF CHIP PRODUCTION BY LOUISIANA HARDWOOD SAWMILLS. La. Agr. Exp. Sta., LSU Wood Util. Notes 6, 2 pp.
Louisiana hardwood sawmills annually produce 345,600 tons of chippable residue, of which only 12 percent is utilized. Since equipment and techniques for chipping pine residues are generally suitable for hardwoods also, many mills could beneficially segregate and market both types of chips. For current costs and market conditions, an average hardwood lumber production in excess of 11,025 board feet per day is necessary for a profitable chip operation. Twenty-seven Louisiana hardwood mills have this capability. If chippers were installed the total potential volume would be in excess of 236,000 tons per year, with a market value of about $1,375,000.

CHIPPING HEADRIGS AND EDGERS

Anonymous. 1967. "CHIP-O-MATIC" EDGER. South. Lumberman 215(2677): 28.
A heavy-duty machine manufactured by the J. A. Vance Company edges material up to 4 inches thick and 16 inches wide and simultaneously converts all the edgings into chips. The edger has eight feed rolls (7⅛ inches in diameter with Coleman-type teeth) and two chipper disks on 2-15/16-inch shafts, with four cutting knives and four scoring knives per disk. The infeed table is 10 feet long. Feed speed is about 260 lineal f.p.m. when a ⅝-inch chip is being cut. The chip length can be varied, and automatic or semi-automatic control is available.

Anonymous. 1968. CHIPPER-CANTER MILL PROCESSES SMALL LOGS WITH FIVE-MAN CREW. Forest Ind. 95(7): 68-69.
A five-man crew converts small logs (6 to 16 inches in diameter) into cants and chips with a Stetson-Ross Model 2 Beaver chipping headrig. Cant production is 100 M b.f. daily. Cants are sent by transfer chain to an adjacent sawmill, while chips are blown 300 feet to a storage silo.

Anonymous. 1968. CHIPS, LUMBER PRODUCED BY MANUFACTURING CENTER. Forest Ind. 95(4): 82-84.
Describes an automated manufacturing complex consisting of a combination chip mill and a "Chip-N-Saw" headrig that is expected to achieve an annual production of 45,000 cords of chips and 25 million board feet of lumber. The headrig accepts logs up to 16 inches in diameter and produces approximately 50 percent 2 by 6's and 2 by 8's; other products include 2 by 4's, 2 by 10's, and 6- and 8-inch boards. Material unsuitable for the headrig is sent directly to an eight-knife, 84-inch diameter chipper which can process logs up to 20 inches in diameter. Chips from both operations are shipped by rail to the company pulp mill; lumber is sold locally. Loblolly pine is the primary species.

Anonymous. 1968. LOW-COST CHIP-STUD MACHINE RECOVERS VALUE FROM CORES. Forest Ind. 95(8): 74.
Briefly describes a low-cost chipper-stud machine that processes

6½-inch veneer cores into ⅝-inch chips and a cant that will yield either one 4 by 6, three 2 by 4's, one 4 by 4 and two 1 by 4's, or six 1 by 4's.

Anonymous. 1968. NEW "BEAVER" CHIPPER CANTER STARTS UP AT J. P. LEWIS CO., BEAVER FALLS, N. Y. Northern Logger 16(9): 8-9, 38. *See also* Pease, D. A. 1969. CHIPPER-CANTER RECOVERS LUMBER FROM PULPWOOD. Forest Ind. 96(2): 84-85.
Describes a chipping headrig operation that processes 8-foot spruce and balsam fir logs having maximum diameters of 24 inches. Fifteen cords per hour are processed at 183 f.p.m. to yield 8 tons of ⅝-inch chips and 5 M b.f. of cants. Chips are converted into refiner groundwood, while cants are sold for conversion into 8-foot, 2- by 4-inch studs.

Anonymous. 1968. PROCEEDINGS, HIGH-SPEED HEADRIG CONFERENCE. State Univ. Coll. Forest. Syracuse Univ., 103 pp. N.Y.
Contains presentations by various authors. Peter Koch reviewed the development of the chipping headrig and described various commercial machine types. L. H. Hobbs noted economic aspects of chipping headrigs, including their advantages and disadvantages. Earl R. Priegel made economic comparisons between a conventional sawmill, a conventional sawmill with a chipping headrig, and a scrag mill. John R. Blackstock examined sawmilling from 1930 to the present and described the use of scrag mills, double arbor edgers, quadsaws, and twin-saw headrigs. J. Dobie discussed the productivity of chipping headrigs, scrag mills, and gang mills. Fredrick B. Malcolm discussed future sawmill research and reviewed technical advances that may lead to automated sawmilling. Also included in the publication are edited versions of panel presentations by operators of six mills with newly installed, high-speed headrigs.

Anonymous. 1969. HARDWOOD PROCESSED BY CHIPPER HEADRIG. Forest Ind. 96(11): 90-91.
Describes an application of a Chip-N-Saw headrig to make hardwood lumber, principally for pallets and crating. The headrig processes mostly beech, birch, hard and soft maple, and cherry logs as large as 20 inches in diameter. With straight, sound wood, it can produce 40,000 board feet per shift. Defective and extremely small logs are not processed by the headrig but are chipped at the infeed end of the mill. All chips are transported by truck to pulp and paper plants. Sawdust and fines are sold locally for agricultural uses, although the company plans to process and sell bark to accomplish 100-percent utilization. All hardwoods are processed satisfactorily when carbide-tipped saws are used in the horizontal arbor section.

Bryan, R. W. 1968. CHIPPER-CANTER REPLACES SCRAGG IN MODERNIZATION. Forest Ind. 95(9): 74-75.
A Stetson-Ross No.4 Beaver was modified to increase its effectiveness in converting southern pine. The changes included: (1) installation of 1⅛ inch spirally set knives in a segmented head; (2) replacement of the air cushion device with a single 10-inch air cylinder with rocker arms; (3) installation of an Esco steel H-type infeed chain and an extra feed roller to accommodate 8-foot logs; and (4) modification of motors to reduce replacement time.

Bryan, R. W. 1969. BAND HEADRIG, CHIPPER-QUADMILL GIVE NEW SAWMILL VERSATILITY. Forest Ind. 96(4): 101-103.
At Temple Industries' new two-sided sawmill at Diboll, Texas, large, high-quality logs go to a band headrig while logs from 6¾ to 18 inches in diameter are processed by a Chip-N-Saw The bandmill has a capacity of approximately 5 M b.f. an hour, while output of the Chip-N-Saw ranges up to 10 M b.f per hour, depending on log diameter and length. Total production is expected to reach 50 to 60 million board feet annually upon completion of improvements. Four bandsaws at the outfeed end of the Chip-N-Saw move independently, providing seven cutting patterns. Cants continue directly to a double arbor edger, while side boards can be directed to either of two side-chipping edgers. On the bandmill side, boards that require edging go to a chipping edger, while timbers are directed to a 36-inch timber saw. Chips from the Chip-N-Saw and a 50-inch horizontal chipper are utilized by Temple's fiber board plant or shipped to pulp and paper mills.

Bryan, R. W. 1969. CHIP HEADRIG UTILIZES MATERIA FROW THINNINGS. Forest Ind. 96(10): 80-81.
Loblolly and shortleaf pine logs, ranging in diameter fro 5½ to 15 inches (average 7 to 8 inches), are sent through Can-Car Mark Chip-N-Saw which can make a 4-inch cant an 1 by 4, 1 by 6, 2 by 6, 2 by 8,and 2 by 10-inch sideboards. Th cant, which proceeds directly to a Can-Car vertical double-arbo edger, yields from two to five 2 by 4's. Logs having diameter greater than 10 inches can be directed to the company's nearb pine sawmill. The mill averages 45,000 to 50,000 feet lumb scale in an 8-hour shift. Annual goal is 12 million feet p shift.

Bryan, R. W. 1969. MEMORY SYSTEM CONTROLS SAWIN IN CHIP-CANT MILL. Forest Ind. 96(4): 106-107.
Reports a system of manufacturing lumber with a No. 2 Beav chipping-headrig in conjunction with a quad bandmill and double-arbor edger. Processing of the logs is controlled a memory system. The mill runs on longleaf and slash pi logs that are at least 7 inches in diameter and 16 feet lon

Bryan, R. W. 1969. SLABBING CHIPPER AT HEADRIG BOOS REMODELED MILL'S OUTPUT. Forest Ind. 96(12): 94-95.
The first slabbing chipper to be used in the United States u manufactured by Chipper Machines & Engineering Corporati The chipper (Model 34) is teamed with a Salem 8-foot ban mill and Cox 48-inch carriage. It is located just ahead of t headrig and removes a slab in the form of chips while t bandsaw makes the first lumber cut. A board and pulpa chips are thus made in a single pass of the carriage. The ch per-bandmill combination produces 30 to 35 percent m than the circular headrig it replaced. Chip production avera 100 tons a day.

Dobie, J. 1967. CHIPPER HEADRIG PRODUCTIVITY CU SMALL LOG MILLING COSTS. Forest Ind. 94(9): 82-85.
Processing costs were determined for three chipping head installations (two Chip-N-Saws and a Beaver) cutting logs to 14 inches in diameter. Costs varied but were about t those for conventional mills. Sawdust comprised only 5 perc of the total volume converted, as compared to 20 to 25 p cent for circular and scrag mills. The saving achieved by m ing chips rather than sawdust was between $60,000 to $90,0 per 25 million board feet of lumber output.

Kaiser, H. F., and Jones, C. A. 1969. CHIPPING HEAD-R CAN HELP MAINTAIN PROFITS IN SOUTHERN SAWMI South. Lumberman 219(2728): 141-142.
A conventional mill was modified by separating a band and a chipping headrig into two separate lines. The mill able to process 22.6 M b.f. of logs per hour—a 24-per

increase. Logs 16 inches and larger were sawn on the band-mill, while smaller logs were diverted to a chipping headrig. The yields of lumber (Doyle scale) of lumber and weight of chips from the chipping headrig are shown in the following table:

Log size class (inches)	*Dimension lumber*	*Boards*	*Total lumber*	*Chip weight*
		Board feet		*Pounds*
[1]5.5-6.4	4,650	0	4,650	36,000
[1]6.5-7.4	2,780	610	3,390	17,470
7.5-8.4	2,290	340	2,630	10,780
8.5-9.4	2,200	0	2,200	7,540
9.5-10.4	1,840	160	2,000	5,780
10.5-11.4	1,670	180	1,850	4,900
11.5-12.4	1,630	110	1,740	4,300
12.5-13.4	1,620	10	1,630	3,870
13.5-14.4	1,560	0	1,560	3,510

[1]Six-inch logs scale 4 bd. ft. and 7-inch logs scale 9 bd. ft.; common practice would assign 16 bd. ft. to such logs.

Lumber production for the modified mill was increased 34 percent, while chip production was increased 43 percent.

Koch, P. 1968. CONVERTING SOUTHERN PINE WITH CHIPPING HEADRIGS. Proc., Forest Eng. Conf. ASAE Pub. PROC-368, pp. 106-111.
Describes events leading to the development of the chipping headrig, with emphasis on the author's research in the years 1953-1963. The three major cutting configurations (planing, end-milling, and shaping lathe) are discussed and their power requirements compared. Commercial machines are described and illustrated. Aspects of productivity are discussed and performance is compared to that of sash gangsaws and scrag mills.

Loffler, H. 1968. THE ECONOMICS OF PROFILER-CHIPPERS. Holz-Zentralbl. 94(22): 353-354.

Morley, P. M. 1968. CHIPPER HEADRIGS FOR PROCESSING SMALL LOGS. Forest. Chron. 44(3): 30-32.
Briefly describes four types of chipping headrigs operating in different mills.

Pease, D. A. 1969. CANT MILL'S INCREASED OUTPUT BALANCES RESAW REQUIREMENTS. Forest Ind. 96(11): 88-89.
By replacing a circular headrig and scrag sawmill with a Stetson-Ross No. 4 Beaver chipper-canter, a lumber company doubled its production. The Douglas-fir cants are used in an affiliated manufacturing operation that averages 125 M b.f. per shift, as compared with 60 to 65 M b.f. per shift for the old sawmill. Maximum capacity of the chipper-canter is 24 inches, but a limit of 18 inches has been adopted for economic reasons. Chips are blown to a double carloader spanning two spur tracks.

Pease, D. A. 1969. CHIPPER-CANTER RECOVERS LUMBER FROM PULPWOOD. Forest Ind. 96(2): 84-85. *See also* Anonymous. 1968. NEW "BEAVER" CHIPPER-CANTER STARTS UP AT J. P. LEWIS CO., BEAVER FALLS, N.Y. Northern Logger 16(9): 8-9, 38.
Describes operations at a papermill in which all incoming spruce and balsam fir roundwood is sent to a chipping headrig. The headrig supplies the mill with refiner groundwood chips and recovers 15 M b.f. of cants per day. The cants are sold for conversion into studs.

Shepard, H. 1968. OPERATION AND USE OF THE SLABBER-HEAD CHIPPER. Northern Logger 17(2): 12-13, 66-67.
Describes a slabbing chipper which consists of a heavy-duty revolving disk having eight knife holders. The knives have a right-angle shape and remove chips in a two-stage cut. The chipper is adjacent to a conventional saw carriage and the leading edges of the knives are in the same position relative to the carriage as the saw. After the log has been dogged, the slabbing head cuts off a face approximately 15 inches wide and 3½ inches deep, producing ⅜-inch chips for pulp. The rate of carriage travel and revolutions of the cutterhead are synchronized. The chipper may be permanently installed to slab one side of the log in a single pass of the carriage, after which the log is sent to a sash gangsaw. The unit can also be installed on a sliding base directly ahead of a circular or band headrig, so that when slabbing has been completed, the carriage can continue past the headrig to cut a board.

Timofeev, N. I., and Gofman, A. I. 1969. CHIPPER HEADS FOR PROFILING LOGS INTO CANTS AND PRODUCING CHIPS. Derev. Prom. 18(4): 7-9.

MOBILE CHIPPERS

Anonymous. 1968. (Chipping, Flaking, and Grinding; Mobile Chippers)

Anonymous. 1968. FIRST TURBINE-POWERED MOBILE DEBARKER-CHIPPER. South. Lumberman 217(2695): 27-28.
The 22-inch "Cruiser" Nicholson Utilizer, a new mobile debarker-chipper, is powered by two 360 hp. Caterpillar 5310 turbine engines. It accepts logs with a maximum diameter of 22 inches at the rate of 120 lineal f.p.m. and can chip over 25 cords per hour. The Utilizer is self-contained and is operated by one man. Each turbine weighs 450 pounds and can be transported on public highways. The turbines are cantilever-mounted to a gear unit which transmits power to the cutterhead and to an electric generator which supplies power to the log loader, debarker, bark hog, propulsion, and hydraulic control units. Should the chipper become overloaded, the feedworks is disengaged until cutterhead speed is regained.

Blumenstock, B. 1968. CHIP PRODUCTION WITH THE NICHOLSON UTILIZER. Northern Logger 17(3): 10-11.

Cervenak, P. 1967. GAS-TURBINE POWER TRIMS COST OF CHIPPING TREE-LENGTH LOGS. Pap. Trade J. 151(34): 45.
A description of the Nicholson Utilizer mobile chipper designed for tree-length logs up to 16 inches in diameter.

Hauffe, N. C. 1969. CHIPPING IN THE FOREST. Pulp and Pap. Mag. Can. 70(6): 81-83.
Discusses the historical development of machines designed for chipping in the forest and describes, in general terms, several commercial machines now in use.

Szostak, M. 1968. ON THE MANUFACTURE OF COARSE CHIPS FROM PINE BRANCHWOOD. Holztechnologie 9(1): 31-34.
Comparative tests were made with four transportable chippers: (1) Karhula 1200/2 (Finland); (2) ITD-1000 (Poland); (3) HZM-Klockner (West Germany); and (4) Spiral-Schnitzler 700-A (Sweden). Best results were obtained with the Finnish Karhula 1200/2. Technical properties of the chips and performances of all machines are described and tabulated.

Zidkov, V. G., Lah, E. I., and Livanov, A. P. 1968. TRIAL OF THE LT-7 CHIP-CARRIER. Lesnaya Prom. (1): 21-22.

Describes trials with a Soviet tipping semitrailer having a load capacity of 11.5 metric tons (36.2 cu.m.).

FLAKING

Lutz, J. F., Heebink, B. G., Panzer, H. R., and others. 1969. SURFACING SOFTWOOD DIMENSION LUMBER TO PRODUCE GOOD SURFACES AND HIGH VALUE FLAKES. Forest Prod. J. 19(2): 45-51.

Four types of cutting methods were evaluated as means of blanking softwood dimension lumber while simultaneously producing flakes for particleboard. Methods included a simulated planer head, a disk flaker, and an experimental blanker equipped with a single knife and a three-stepped knife. In Douglas-fir, flakes were stronger and less curled when cut with the experimental blanker and the disk flaker, although the planer-head method produced slightly less fines and yielded smoother surfaces on the blanks. The flakes from the experimental blanker and the disk flaker were similar in dimensions and appearance, and yielded boards of equal dimensional stability and strength. Boards made from planer shavings had greater linear movement and less strength in bending than did boards made from flakes.

GRINDING

No articles found.

DEFIBRATING

Anonymous. 1968. (Chipping, Flaking, and Grinding; Chipping Headrigs and Edgers)

Anonymous. 1968. MAKING REFINER GROUNDWOOD IN CANADA, U. S. A., AND EUROPE. Can. Pulp and Pap. Ind. 21(6): 58-59.

Briefly describes five refiner groundwood mills in Canada, the United States, and Europe.

Allan, R. S., Skeet, C. W., and Forgacs, O. L. 1968. REFINER GROUNDWOOD FROM DECIDUOUS SPECIES. Pulp and Pap. Mag. Can. 69(18): 74-80.

A modified 412 Bauer double-disk refiner, a Bauer 560-GS Impressafiner, and supplementary feeding and stock-collecting equipment were used to explore the mechanical pulping potential of several hardwoods (trembling aspen, red maple, white and yellow birch, and sugar maple). Experiments were limited to direct chip refining and refining after mild pretreatment in the Impressafiner. The properties of newsprint groundwood from spruce were taken as target quality. Aspen was the only species that could be pulped to reasonable strengths and freenesses by direct reduction. The addition of sodium hydroxide to either the feed or the expansion chamber of the Impressafiner increased pulp strengths for all species, although it was not possible to reach target strength with the maple chips. Brightness was reduced in all cases when the caustic was added to the expansion chamber. With aspen and white birch, brightness in the 54 to 58 point range could be obtained by adding sodium sulphite to the impregnation liquor. The brightness of yellow birch and the maples was about 10 to 15 points below this level, and the pulps would have required bleaching to be acceptable for newsprint. The refining energy required for a given freeness level could be reduced by using fine rather than coarse plates, and there were indications that further reductions could have been attained by increasing peripheral disk speeds in the second stage of refining. Impregnation with 2-percent cold soda (ovendry basis) reduced the energy requirements at a given freeness level and improved the bonding efficiency of the available fiber surface. At constant refining energy, weight average fiber length (L value) was decreased by the use of fine plates but increased as a result of sodium hydroxide impregnation, indicating less failure across the cell wall. The authors suggest that the strength properties of the green wood may have an important bearing on the level of chemical treatment and refining energy.

Asselin, A. 1969. GROUNDWOOD PRODUCTION WITH THE NEW CONTROLLED DEPTH BURR. Pulp and Pap. Mag. Can. 70(C): 151-152.

Recently developed burrs for dressing groundwood pulp stones maintain a constant depth of penetration, thus producing the same land area from one pulpstone sharpening to the next. The burrs have a tooth length one-third to one-half that of standard burrs and limit penetration of teeth to the average pattern depth used in groundwood manufacture. Industrial tests indicated that sharpening was easier than with conventional burrs, fewer sharpenings were required, and costs were lower.

Beloit Corp. 1968. (Patents)

Braun, R. V., and Davis, J. W. 1969. PRINTABILITY AND STRENGTH QUALITIES OF REFINER GROUNDWOOD AS RELATED TO WOOD SPECIES. TAPPI 52: 282-288.

Stone and refiner groundwoods were prepared from red and white fir, Douglas-fir, incense-cedar, white spruce, sugar, ponderosa, and southern pine, and their properties evaluated. Poplar stone groundwood was used as a reference. The refiner groundwoods were generally superior to stone groundwoods in strengths (especially tear), but inferior in printability. Printability appeared related to fiber coarseness, fiber size, cell wall thickness, and the proportion of coarse fraction in the pulps (+28 and +48 fractions). Removal of these fractions improved the printing properties of coated handsheets. Southern pine had improved strength (especially tear) at higher refining consistencies, while printability was improved by controlling the coarse fraction and refining to lower freeness. Poor printability may be magnified in refiner groundwood from species containing coarse fibers or high percentages of summerwood.

Eberhardt, L. 1968. HI-YIELD AND MECHANICAL TYPE PULP FROM RAW MATERIALS OF INDIA. Indian Pulp and Pap. 23(1): 49-51.

Tabulates and discusses the suitability of various Indian species including tropical hardwoods, eucalyptus, and bamboo, for high yield and refiner groundwood pulping.

Fuentes, E. F. 1968. MANUFACTURE OF CHIP GROUND WOOD. ATCP 8(5): 375-381.

The refiner groundwood process is reviewed in some detail. Aspects considered include its advantages over conventional stone groundwood, use of chip pretreatments ("Pressafiner" or "Impressafiner"), operating characteristics and arrangement of disk refiners, stock consistency, refining action on chips, energy consumption, and economics on the process.

Giese, E. 1968. BASIC KNOWLEDGE FOR THE MANUFACTURE OF MECHANICAL WOOD PULPS. Papier 22(10A): 721-726.
Groundwood pulps often differ markedly in physical properties, depending on length of storage, density, temperature, and the conditions of sheet formation. These differences are attributed to the "latency phenomena." The author indicates that, to a marked degree, the effects of latency may be manipulated in the course of producing mechanical pulps, and methods for recovering latent strength are discussed. By applying the Atack-Pye concepts, the author shows the similarity in behavior between commercial groundwood and mechanical pulps made in the laboratory. He also attempts to derive a common theory covering defibration by grinding and by refining.

Guha, S. R. D., Dhoundiyal, S. N., and Mathur, G. M. 1968. MECHANICAL PULPS FOR NEWSPRINT GRADE PAPERS FROM MORINGA PTERYGOSPERMA (M. OLEIFERA). Indian Forest. 94(8): 635-638.
The wood of M. oleifera *makes a good mechanical pulp (light color and low density) but develops deep grey patches when stored. If logs are processed immediately after felling, bleaching of the pulp is unnecessary.*

Hatton, J. V. 1968. EFFECT OF OUTSIDE CHIP STORAGE ON REFINER GROUNDWOOD PULP BRIGHTNESS. Can. Dep. Forest. Bimo. Res. Notes 24(6): 48-49.
Brightness loss in lodgepole pine refiner groundwood was as much as 12 to 18 points (Elrepho brightness) for chips stored 3 months, but much of the loss occurred during the first month. Losses in both lodgepole pine and white spruce refiner groundwood were positively correlated (to some degree) with the maximum temperatures recorded in the chip pile. The author recommends that chips be processed with a minimum of delay.

Holokiz, H. 1968. EFFECT OF CHIP SIZE ON WOOD FIBRE PULP AND PROPERTIES OF HARDBOARD. APPITA 21(6): 196-206.
Part I of this paper describes development of a test for analysis of pulp chips; chips were sorted through screens of five sizes and length of chips along the grain was measured for each fraction. Part II reports an attempt to relate chip size (as determined by the screening procedure) to pulp quality, yield, and properties of hardboard produced by the Mason gun process. As chips (regardless of uniformity) became smaller the pulp contained more fines, was easier to compress, and contained more water-soluble constituents. The yield of fibers and the dimensional stability of boards were lowered by a reduction in chip size, but modulus of rupture increased (except for very small chips).

Johnsson, G. 1968. NINE GRINDERS GET COMPLETE NEW LOADING SYSTEM. Pulp and Pap. 42(31): 20-21.
Describes a new loading system for the nine grinders at the Bowaters Svenska Tramassefabriker AB. groundwood mill at Umea, Sweden.

Jones, H. W. H. 1968. CONSOLIDATED-BATHURST EXPERIMENTAL REFINED WOOD PLANT—A PROGRESS REPORT. Pulp and Pap. Mag. Can. 69(16): 51-52.
An experimental plant has been built for investigating variables in making refiner groundwood from both softwoods and hardwoods. The installation has two refiners with 4,000-hp. motors, screening and cleaning equipment, chip pretreating facilities (steaming and shredding), a pneumatic chip blower, and a variety of instrumentation.

Jones and Helleur. 1968. (Patents)

Jones and Helleur. 1968. (Patents)

Leask. 1968. (Reports of Research Programs and Industrial Developments)

McMillin, C. W. 1968. FIBERBOARDS FROM LOBLOLLY PINE REFINER GROUNDWOOD: EFFECTS OF GROSS WOOD CHARACTERISTICS AND BOARD DENSITY. Forest Prod. J. 18(8): 51-59.
The gross wood properties of specific gravity, proportion of latewood, and growth rate affected the strengths of fiberboards in tension and bending, as well as their dimensional stability. For the refining conditions and formation procedures studied, and after allowance for the effect of board specific gravity, most properties were improved by using fiber refined from dense wood having low latewood content. This article is the first of a series of two: see the third abstract following.

McMillin, C. W. 1968. GROSS WOOD CHARACTERISTICS AFFECTING PROPERTIES OF HANDSHEETS MADE FROM LOBLOLLY PINE REFINER GROUNDWOOD. TAPPI 51: 51-56.
Discusses interrelationships between certain gross wood characteristics, refining energy, and the physical properties of handsheets with the objective of developing criteria useful in controlling the papermaking potential of refiner groundwood from loblolly pine. Wood having two specific gravities (less than 0.49 and more than 0.49) and two growth rates (less than 6 and more than 6 rings per inch) at each of three radial positions in the stem (0 to 10, 11 to 20, and 20 to 30 rings from the pith) was selected, chipped, and then double-disk refined at two specific refining energies. After handsheets were prepared from the pulps, the specific gravity of extracted and unextracted wood, growth rate in rings per inch, and proportion of latewood were correlated with sheet density, burst factor, tear factor, and breaking length. Specific refining energy and gross wood properties accounted for as much as 90 percent of the total variation in strength of handsheets. Burst, tear, and breaking length were increased by applying high refining energy and using fast-grown wood with a high proportion of latewood and relatively low specific gravity. Only high refining energy and a high proportion of latewood were required to increase sheet density. Because the latewood content of loblolly pine typically increases with increasing rings from the pith, it is surmised that chips obtained from slabs and edgings of large logs would yield sheets stronger than those made from chips obtained from veneer cores. This article is the first of a series of four; abstracts of the three other articles follow.

McMillin, C. W. 1969. ASPECTS OF FIBER MORPHOLOGY AFFECTING PROPERTIES OF HANDSHEETS MADE FROM LOBLOLLY PINE REFINER GROUNDWOOD. Wood Sci. and Technol. 3: 139-149.
Burst, breaking length, and sheet density were improved by using fiber refined from wood having long, slender tracheids with thick walls. Only slender, thick-walled tracheids were required to improve tear factor. A theoretical stress analysis revealed that thick-walled cells of small outside diameter fail by diagonal tension or parallel shear, depending on the fibril angle, while under torsional stress during refining. Such failures result in ribbonlike fragments which research elsewhere has demonstrated to provide the coherence necessary for

strength development in mechanical pulps. In contrast, thin-walled cells of small outside diameter fail by diagonal compression and yield few ribbons. Long fibers are more desirable than short fibers because of greater induced stresses and improved chances of axial alignment between the disks.

McMillin, C. W. 1969. FIBERBOARDS FROM LOBLOLLY PINE REFINER GROUNDWOOD: ASPECTS OF FIBER MORPHOLOGY. Forest Prod. J. 19(7): 56-61.
Most properties of wet-formed hardboard were improved by using fiber refined from wood having short, slender tracheids with thin walls. A theoretical analysis suggested that the fibers fail in bending while under stress induced by the pressing operation. Such bending failures improve conditions for hydrogen bonding, thus improving board properties. Tracheids having narrow diameters and thin walls flex easily and collapse readily. Short tracheids are more desirable than long tracheids because of a greater number of fiber crossings per unit weight in the pulp mat.

McMillin, C. W. 1969. QUALITY OF REFINER GROUNDWOOD PULP AS RELATED TO HANDSHEET PROPERTIES AND GROSS WOOD CHARACTERISTICS. Wood Sci. and Technol. 3: 287-300.
Pulp quality, in terms of a fiber shape factor S and a fiber length factor L, was determined from 96 pulps disk-refined from chips of varying characteristics. S was evaluated in terms of the Canadian Standard Freeness of the 48/100 fiber length fraction and is a parameter inversely proportional to specific surface. L is the percentage, by weight, of pulp retained on a 48-mesh screen and reflects the distribution by weight of fiber length in the whole pulp. S and L accounted for as much as 83 percent of the variation in handsheet properties. Properties were improved by using pulps displaying low values of S and relatively high values of L. Both S and L were related to specific refining energy and wood quality. S increased with increasing unextracted chip specific gravity and rings per inch of growth rate but decreased with increasing latewood content and refining energy. L decreased with increasing refining energy, rings per inch of growth rate, and unextracted chip specific gravity but increased with increasing latewood.

McMillin, C. W. 1969. WOOD CHEMICAL COMPOSITION AS RELATED TO PROPERTIES OF HANDSHEETS MADE FROM LOBLOLLY PINE REFINER GROUNDWOOD. Wood Sci. and Technol. 3: 232-238.
Burst and tear strengths of handsheets made from 48 pulps disk-refined from chips of varying chemical composition decreased with increasing extractive content after the independent effects of fiber morphology were specified. This result was attributed to lessened bond strength caused by reduced surface tension forces and blocking of reactive sites on the fiber surfaces.

Martin, A. C. 1969. A STUDY OF GRINDER VARIABLES AS PRODUCTION IS INCREASED. Pulp and Pap. Mag. Can. 70(C): 133.
The Abitibi Ste. Anne Paper Company increased production of its No. 7 line from 18.4 to 29.8 cunits per day by turning 80-inch diameter stones (sharpened with standard 12 × 1½ burrs) at 257 r.p.m.

Marton, R., and Robie, J. D. 1969. CHARACTERIZATION OF MECHANICAL PULPS BY A SETTLING TECHNIQUE. TAPPI 52: 2400-2405.
The settling velocity of particles from pulp suspensions was investigated as a possible means of describing their shape and size. The influences of experimental conditions on the repr[o]ducibility and sensitivity of the method were considered. Th[e] settling rate was highly dependent upon coarseness and specif[ic] surface area, and somewhat less dependent on fiber lengt[h]. Physical properties of handsheets prepared from the pul[p] were correlated with the variations in settling rate of 30 sto[ne] and refiner groundwoods and their fractions. The relationsh[ip] between freeness and settling rate, and the relationship betwe[en] mechanical properties and settling rate, differed for stone an[d] refiner groundwoods. The settling-rate test gave informatio[n] that was not evident from freeness results alone.

Montmorency de. 1969. (Chipping, Flaking, and Grindin[g] Chipping)

Morkved, L., and Larson, P. 1969. REFINER GROUNDWOO[D] TAPPI 52: 1465-1467.
Describes startup and operation of a refiner groundwood m[ill] having three identical refiner lines followed by three screenin[g] cleaning, and deckering systems. Each refiner line consists [of] three 4,000 hp. (0.8 power factor) Bauer 480 refiners arrang[ed] in series. The chip feed rate to the first-stage refiner is manua[lly] adjusted, while the second and third stages are automatica[lly] controlled by the pulp weight in the preceding stage sum[p]. The pulp has run well on the paper machine, producing [a] smooth, clean, and strong sheet. The newsprint sheet has be[en] well received by both letterpress and offset printers. Some d[ata] comparing stone and refiner groundwood pulps are a[lso] presented.

Nystrom, E. W., and Okell, R. H. 1969. SAWDUST REFI[N]ING AT CROFTON. Pulp and Pap. Mag. Can. 70(7): 83-[8]
Pulps refined from western hemlock sawdust were compara[ble] to pulps obtained from stone groundwood. Sawdust could [be] stored for as long as 10 days without increasing brightene[ss] costs. When Bauer 480 machines were operated in ser[ies] refining sawdust in three stages was superior to two-st[age] refining.

Ohnishi, K., Awaya, S., and Egawa, K. 1968. HARDWC[OD] REFINER GROUNDWOOD AS A NEWSPRINT FURNISH CO[M]PONENT. Pulp and Pap. Mag. Can. 69(19): 79-83.
The Oji Paper Company, Tokyo, Japan, is currently mak[ing] newsprint with more than 50-percent hardwood pulp obtai[ned] from a mixture of refiner groundwood, chemi-mechanical, [and] semi-chemical pulps. Although hardwood refiner groundw[ood] was inferior to softwood stone groundwood in handsi[eet] strength tests, it was equal in tests of pressroom pe[rf] strength and machine runability. An attempt is made [to] explain this result in terms of: (1) releasability from the p[ress] roll; (2) stress-strain behavior of the wet and dry sheet; [and] (3) relationship between dry sheet strength and wet [and] elongation.

Olsen, W. W. 1969. HIGH-PRODUCTION GRINDING BY [P]LESS AND CONVENTIONAL TECHNIQUES. TAPPI 52: 293-[3]
When compared to conventional grinding at the same sp[ee]d, pitless grinding of various pines resulted in steadier load a[p]plication and slightly improved quality at somewhat lower po[wer] consumption. Grinding at 375, 363, 300, and 250 r.[p.m.] (by both pitless and conventional methods) showed tha[t] the higher speeds, greater power utilization per stone [was] possible and production rates as high as 112 air-dry tons [per] 24 hours could be achieved on grinders producing 53 air-[dry] tons by conventional methods. A satisfactory balance [of] quality and production was achieved. For example, at [375] r.p.m., grinders showed an increase of 30 percent in pro[duc]-

tion while burst and tear were reduced 2 and 9 percent respectively. The quality of groundwood produced at high load and high speed was very sensitive to the frequency of sharpening and to the binding effect of pitch deposits on the stone surface. For both slow and fast speeds, brightness gradually dropped as frequency of sharpening was reduced, but this effect was offset by the improved pulp obtained with the longer sharpening cycles. Trials with a stone of different composition reduced the sharpening frequency and increased the +28 fraction, burst factor, and tear factor while still maintaining a high production rate. The effects on newsprint quality were also beneficial, and significant increases in printability, ink transfer, and show-through have been demonstrated on a laboratory proof press for the high-speed pitless groundwood.

Packman, D. F. 1967. PULPING OF BRITISH-GROWN SOFTWOODS. V. DISC REFINING OF CHIPS FROM VARIOUS SPECIES. Pap. Technol. 8(4): 339-340.
Groundwood pulp was made on a laboratory refiner from chips of British-grown Sitka spruce, Scotch pine, Douglas-fir, grand fir, western hemlock, and Japanese larch. Pulp suitable for the manufacture of high-grade folding boxboard was produced from mixtures of the chips. Considerable variation in composition of the mixture could be tolerated without substantial loss of quality in the product.

Peakes, D. E. 1969. CHARACTERIZATION OF PUBLICATION-GRADE STONE GROUNDWOOD. TAPPI 52: 64-67.
Magazine-paper groundwood pulps made on three commercial grinders were sampled over a 3-month period and their length (L) and shape (S) factors were determined by the method of Forgacs. L was highly correlated with freeness, strength, optical properties, calendared sheet smoothness, and print rating; the coefficients of determination (r values) ranged from 0.73 to 0.95. S had low correlation with all properties except breaking length (r = 0.66). Multiple regression analysis, including both L and S, on the response variables improved the fit slightly.

Polcin, J., Wayman M., Anderson, C. B., and Rapson, W. H. 1969. SAPWOOD AND HEARTWOOD GROUNDWOOD OF WESTERN HEMLOCK AND JACK PINE. I. INFLUENCE OF EXTRACTIVES ON OPTICAL PROPERTIES. Pulp and Pap. Mag. Can. 70(21): 91-98.
The removal of extractives from groundwood pulps of western hemlock and jack pine heartwood and sapwood moderately improved the brightness and spectral reflectivity in the total visible region and the optical stability towards thermal aging. Pulps of jack pine heartwood showed the highest color reversion by the thermal aging treatment. Improvement in brightness and color reversion by the EDTA treatment was attributed mainly to the removal of metallic cations. Infrared and ultraviolet spectroscopy indicated that the main components of the ethanol-benzene extracts of western hemlock groundwood were lignins, fats, and some resin acids. The components of the ethanol-benzene extracts of jack pine groundwood were resin acids, fats, and only a very small amount of phenolic compounds. The removal of extractives soluble in ethanol-benzene (1:2) mixture did not improve the color of pulps, but improved the stability towards thermal aging, especially in jack pine heartwood. It thus appeared that the resins, like phenolic compounds, have some effect on the color reversion of groundwood. Acetone-water (1:1) extraction of groundwood pulps pre-extracted with ethanol-benzene removed polyphenols, lignins, and some low-molecular fraction of lignin-like compounds. Because these substances (especially in a polymeric form) are colored, acetone-water extraction slightly improved the brightness and spectral reflectivity in the whole visible region. Stability towards thermal aging was also improved.

Scoble, F. J., and Greener, A. A. 1968. THE MANUFACTURE OF REFINER GROUNDWOOD FOR CARTON BOARD. Pulp and Pap. Mag. Can. 69(20): 73-79.
Thames Board Mills Ltd. at Workington, Cumberland, England, produces refiner groundwood from softwood thinnings. About 65 percent Norway and Sitka spruce, 15 percent larch, and 20 percent Scotch pine and Douglas-fir are used to manufacture a duplex folding boxboard comprised of a bleached pulp liner (coated or uncoated) with filler and backs of groundwood. The advantages of refiner groundwood are claimed to outweigh the higher power costs. The stock preparation system includes two identical lines, each having two 2,000-hp. Vertifiners in series followed by conventional screens and centricleaners.

Service, G. 1967. PRODUCTION OF REFINER GROUNDWOOD FROM WEST COAST SAWDUST. Pap. Trade J. 151(21): 40-43.
Reports on handling, storage, and treatment processes at MacMillan Bloedel Ltd. Four Bauer double-disk refiners produced 90 ovendry tons per day of groundwood pulp from material originating at gangsaws and edgers—mostly full-length fibers and small chips. Pulp from Douglas-fir was inferior in all respects to that from hemlock.

Trevelyan, B. J. 1969. MECHANICAL PULPING OF SOUTHERN PINE WOOD. Forest Prod. J. 19(1): 29-38.
Three charcteristics of the southern pines—high latewood content, high resin content, and susceptibility to blue stain—have been the source of major difficulties in attempts to make satisfactory groundwood pulp. The paper reviews the 30-year history of newsprint production in the South, placing special emphasis on the techniques employed by industry to overcome these problems. Modern operating practices are discussed, and opportunities for future improvements are presented. The author suggests that disk refining offers considerable potential for improving the properties of mechanical pulps from southern pine. Current statistics on U.S. groundwood production indicate that over half the expansion in the newsprint industry is taking place in the South.

Ullman, U. 1969. GROUNDWOOD QUALITY CONTROL—CORRELATION OF PAPER PROPERTIES WITH PULP PROPERTIES. TAPPI 52: 834-838.

Underhay, G. F. 1968. MECHANICAL PULP—THE NEGLECTED GOLD MINE. TAPPI 51(9): 39A-48A.
Increased use of mechanical pulp, especially for newsprint, would cut costs, utilize timber more efficiently, minimize effluent problems, and improve sheet properties. Commercial mill runs have demonstrated that additions of chemical pulp are unnecessary. Moreover, experiments on both sides of the Atlantic show promise for extending mechanical pulp to magazine and other paper grades, but a critical evaluation of test methods and closer control of machine operating variables will be needed to prevent losses in efficiency when using furnishes with high mechanical pulp contents. Rapid advances may be expected when a nondelignifying bleaching process has been developed for improving the brightness and photostability (yellowing resistance) of mechanical pulps.

Vecchi, E. 1969. QUALITY CONTROL OF POPLAR GROUNDWOOD: FACTORS RELATED TO THE STRUCTURAL COMPOSITION OF THE PULP. TAPPI 52: 2390-2399.
Morphological analysis of poplar groundwood showed the presence of several ribbonlike fibrous particles from tension wood. The characteristics and properties of single fractions obtained from a Bauer-McNett classification on screens ranging from 28- to 500-mesh showed that each fraction influenced the properties of the whole pulp. Poplar groundwoods did not exhibit high mechanical strength, but their opacity, porosity, bulk, and brightness made them suitable for printing paper. Only two tests are necessary to evaluate pulp quality: a drainage measurement and a Bauer-McNett classification. From the latter the weighted-average fiber length and the fiber-length distribution may be calculated. Regression analysis indicated reasonable correlation between the papermaking properties of the pulps and these variables.

Yli-Paavola and Tampella. 1968. (Patents)

PROPERTIES OF THE CUTTING EDGE AND CUTTER

TOOL MATERIAL

Barz. 1968. (Properties of the Cutting Edge and Cutter; Dulling)

Beck. 1969. (Sawing; Sash Gangsawing)

Haidt, H. 1968. THE USE OF HARDALLOY—TIPPED CIRCULAR SAW BLADES. Holz als Roh- und Werkstoff 26: 401-408.
The effects of sawing methods, tooth shape, tooth geometry, and the number of teeth are discussed in relation to the quality of cut. Other factors considered are depth of cut, kerf, feed speed, cutting speed, and protrusion of the blade. Power requirements and general operating instructions are also given.

Olszewski, J. 1967. TRIAL IN THE USE OF CERAMICS FOR (THE TEETH OF) CIRCULAR SAWS FOR CUTTING PARTICLE BOARDS. Zeszyty Nauk. Szkola Glowna Gosp. Wiejskiego (1): 71-94. Warsaw.

Yamaguchi, K. 1967. ELECTROARC DEPOSITING OF HARD METAL ON SAW TOOTH. *In* Forest Exp. Sta. Bull. 200, pp. 212-226. Meguro, Tokyo.
Seven materials were tested for hardening the teeth of bandsaws. JSE 3A (83 to 89 percent tungsten, 5 to 8 percent cobalt, 5 to 6 percent carbon) and JEC 4A (unspecified) gave smooth surfaces and were deposited with ease. Stellite gave a rough surface and was difficult to deposit.

DULLING

Barz, E. 1967. PROLONGING THE WORKING LIFE OF WOODWORKING TOOLS BY REDUCING WEAR ON BACK SURFACES. *In* IUFRO Congr. Proc. 1967, Vol. 8, Sect. 32, 18 pp. Munich.
When highly abrasive materials were being cut, chromium plating proved best of various treatments.

Barz, E. 1968. LENGTHENING THE CUTTING LIFE OF WOODWORKING TOOLS BY HARD CHROMING. Bois Forets Trop. 118: 56-62.
After preliminary treatment, unalloyed, light-alloy, and high-speed steel were suitable for hard-chromium plating. Hard-chromium plating is recommended for woodworking tools sharpened only at the face or back, or if tipping with carbide is unsuitable. When chromium-plated knives were sharpened only on the front face, a self-sharpening effect prolonged service life. The improved wear of chromium plated tools was attributed to reduced friction and chemical and electrochemical deterioration.

Byzov, V. I. 1968. EFFECT OF THE DULLING OF FRAME-SAW TEETH ON SAWING. Derev. Prom. 17(6): 5-8.

Chardin, A., and Froidure, J. 1967-1968. THE WEAR OF SAW TEETH. II. APPLICATION OF THE METHOD ADOPTED. Bois Forets Trop. 1967(116): 15-30; 1968(120): 49-65.
Wear tests were made with circular saws having a sing inserted tooth but operated under conditions similar to ban sawing. Special equipment was used to produce accurate cu ting edges of high quality. Wear was evaluated by thr methods: the amount of metal lost on the clearance fac profiles obtained from photographic enlargements; and phot graphic comparisons of the tooth before and after cuttin The force parallel to the cutting direction was measured a changes in chip flow were observed by high-speed photo raphy. Quality of sawn surfaces was evaluated empirical but the change in the temperature of the tooth was record with microthermocouples. Techniques under developme should establish better correlation between results obtain in the laboratory and the behavior of sawblades in industri practice. Translation available from Commonwealth Scienti Industrial Research Organization Australian Transl. 9238, 19 14 pp.

Chardin, A., and Froidure, J. 1968. TESTS ON THE WE OF SAW TEETH. III. METHOD OF PUBLICATION OF RESUL Bois Forets Trop. 122: 41-58.

Dem'janovskij, K. I. 1968. THE WEAR RESISTANCE TOOLS FOR ROTARY CUTTING OF WOOD. 128 pp. Mosco Izdatel'stvo 'Lesnaja Promyslennost'.

McKenzie, W. M., and McCombe, B. M. 1968. CORROS WEAR OF VENEER KNIVES. Forest Prod. J. 18(3): 45-46.
Knife wear in peeling green alpine ash (Eucalyptus dele tensis) *was minimized by holding the knife at a negat potential of 60 volts with respect to the nosebar.*

Pahlitzsch, G., and Dziobek, K. 1968. INVESTIGATIONS THE WEAR CHARACTERISTICS OF A CUTTING TOOTH. Holz Roh- und Werkstoff 26: 162-170.
Wear was investigated with an apparatus in which a sin point tool was used to turn high-density plywood (compres wood). The effects of tooth form, cutting angle, accuracy sharpening, feed rate, cutting forces, and edge temperat were related to the quality of the cut surface and tool w The results are presented mainly in three-dimensional gra Electron micrographs illustrate tool wear.

FITTING AND SHARPENING

Anonymous. 1968. CARE OF CUTTERS. Inform. Bull. T ber Res. Develop. Assoc., High Wycombe I/IB/12, 10 England.
The care of cutters of all types used in planing and mold is considered, except cutters tipped with tungsten carb Setting of cutters and methods of minimizing edge blun

caused by wood extractives are mentioned. The need for safety is stressed. Books on the subject are listed.

Anonymous. 1968. THE MAINTENANCE OF SAWS FOR CUTTING WOOD. Forest Prod. Res. Lab. Tech. Note 30, 9 pp. Princes Risborough, England.
Briefly describes procedures for leveling, tensioning, sharpening, and setting band and circular saws.

Anonymous. 1969. ADVANCES IN SHARPENING TECHNIQUES FOR SAWS. Holz als Roh- und Werkstoff 27: 119-120.

Anonymous. 1969. (Veneer Cutting)

Bajkowski, J. 1967. DISTRIBUTION OF STRESSES IN FRAME-SAW BLADES PRE-STRESSED BY ROLLING. Holztechnologie 8(4): 258-262.
Describes the compressive stresses and compensating tensile stresses produced by rolling framesaw blades at various intensities. Stress distributions leading to optimum rigidity (slight asymmetry towards the back edge) are discussed.

Bajkowski, J. 1968. EFFECT OF ROLLER-TENSIONING OF FRAME-SAW BLADES ON THE INCREASE IN RIGIDITY AND DISTRIBUTION OF INTERNAL STRESSES. Zeszyty Nauk. Szkola Glowna Gosp. Wiejskiego (2): 97-112. Warsaw.
Tensioning should be performed by rolling three parallel lines on the saw blade—one down the center, the others 25 mm. on either side. The load on the rolls should be about 2,000 kg.

Barz, E., and Munz, U. V. 1968. TESTING AND DETERMINATION OF THE SET AND STRESS-STATE IN CIRCULAR SAW BLADES FOR WOOD. Holz als Roh- und Werkstoff 26: 170-175.
Reviews test methods for determining the set and state of stress (tension) in circular saw blades. A testing machine developed at the Institute for Tool Research at Remscheid, Germany, is described. The diagrams produced by the apparatus give a more precise indication of the condition of the saw than does hand testing; they thus facilitate the manufacture of accurately matched saws and evaluation of changes that occur in use.

Bunimovic, E. E. 1969. NEW METHOD OF SPRING-SETTING THE TEETH OF CIRCULAR SAWS. Derev. Prom. 18(1): 14-16.
Simultaneously with the bending of the tooth, a compressive load is applied in a direction perpendicular to the blade surface at the point of maximum stress concentration. An experimental machine for setting teeth in this manner is described.

Cowling, R. L., and McKenzie, W. M. 1969. LAPPING OF STEEL TOOLS FOR MAXIMUM SHARPNESS. Wood Sci. 2: 20-25.
A stable cutting edge having a radius of about 0.2 um was produced on tool steel with 2 percent carbon and 12 percent chromium. Methods for sharpening and measuring sharpness, and the influence of materials and techniques on initial sharpness, are discussed.

Dem'janovskij, K. I., Pinezskij, D. I., and Terent'eva, G. J. 1968. INVESTIGATIONS ON THE SHARPENING OF CIRCULAR SAWS FOR CROSS-CUTTING WOOD. Derev. Prom. 17(4): 13-15.
The bluing of teeth during sharpening was studied in relation to the hardness and structural changes of the metal in the discolored zone. The wear resistance of teeth with various amounts of discoloration is also discussed.

Godin, V. 1968. THE GRINDING OF VENEER KNIVES. Can. Dep. Forest. and Rural Develop. Dep. Pub. 1236, 23 pp.

Hayashi, Tochigi, and Eguchi. 1969. (Veneer Cutting)

Shanks, J. W. 1968. F.P.R.L. CONTINUOUS SIDE DRESSER. Timber Trades J. 267(4813): 55, 57.
Describes a simple, hand-operated tool for side dressing wide bandsaw teeth. Tool requires less skill and gives more uniform tooth widths than do conventional hand-operated dressers.

Sannikov. 1968. (Research Instrumentation and Techniques)

STABILITY

Anonymous. 1967. NEW SAWBLADE TESTING DEVICE. Timber Trades J. 263(4754): 65-66.
An electronic device manufactured by Otto Jorg Metallwaren, Oberstaufen, Germany, automatically measures and records lateral deflections of bandsaw blades during cutting. It is claimed that the device will permit high feed speeds without sacrifice of dimensional accuracy in the sawn timber.

Grube, A. E., Sanev, V. I., and Paskov, V. K. 1967. AUTOMATIC REGULATION OF TEMPERATURE STRESS IN CIRCULAR SAWS. Derev. Prom. 16(8): 4-6.
Describes various laboratory systems for automatic regulation of temperature stresses, i.e., reduction of the temperature gradient along the blade radius. These systems heat the central part of the blade with friction blocks that are automatically brought into contact when roller or induction pickups at the blade periphery detect a deviation from the normal position. In factory trials it was possible to use blades thinner than ordinary, and with less spring set. Accuracy and quality of sawing were also improved.

Grube, A. E., Sanev, V. I., and Paskov, V. K. 1968. TRANSVERSE OSCILLATIONS OF CIRCULAR SAWS FOR RIP-SAWING WOOD. Les. Zh. 11(1): 79-83.
With untensioned blades having a thickness-to-diameter ratio of less than 0.0036 to 0.0040, resonant oscillations occurred in the range of 750 to 3,000 r.p.m. Increasing the diameter of the saw collar and tensioning the blade center reduced the frequnecy and magnitude of the oscillations.

Grube, A. E., Sanev, V. I., and Paskov, V. K. 1969. DAMPING THE TRANSVERSE OSCILLATIONS OF CIRCULAR SAWS. Lesnaya Prom. (2): 18-20.

Hallock. 1968. (Sawing; Circular Sawing)

Stahiev, J. M. 1967. THE RIGIDITY OF CIRCULAR-SAW BLADES FOR CUTTING WOOD. Les. Zh. 10(4): 113-115.
Theoretical studies were made of blade rigidity for a disk loaded by a transverse concentrated force at its periphery, i.e., for nonsymmetrical bending of a thin round plate. The rigidity of saws 300 to 700 mm. in diameter and 1 to 3 mm. thick was calculated for various ratios of collar diameter to disk diameter. Rigidity was a cubic function of disk thickness, whereas the stability of the plane equilibrium of the disk (characterized mainly by the critical temperature gradient along the radius) was a quadratic function of disk thickness. Rigidity increased with increasing collar diameter.

TEMPERATURE

Cumming, J. D., and Gill, G. S. 1968. TEMPERATURE GRADIENTS AND THERMAL STRESSES IN CIRCULAR SAWS. Wood Sci. 1(2): 86-92.
Discusses circular saw instability in relation to thermal gradients caused by energy dissipated in the cutting process and by frictional rubbing of the saw against the wood. The distribution

of temperature in a rotating disk was measured and shown to be in reasonable agreement with values predicted from mathematical analysis of heat transfer in the plate and heat convection through its surface into the surrounding turbulent boundary layer of air. Several methods are suggested for reducing the temperature gradient between the inner portion of the saw and the outer rim.

Okushima, S., Sugihara, H., and Umemoto, M. 1969. TEMPERATURE OF CUTTER-CUSP IN WOOD CUTTING. J. Jap. Wood Res. Soc. 15(5): 197-202.
The distribution of temperature in the neighborhood of a cutter edge was measured with an infrared radiometric microscope. Temperature 2 mm. from the cusp became constant (approximately 400° C.) after an edge without set had cut 400 cm. of wood 38 mm. thick at a feed speed of 10 m. per minute. The temperature of a tooth without set was greater than that of a tooth with set. Temperature increased wit increasing cutting and feed speeds. High temperatures rapidl reduced surface hardness at the cutting edge.

Tverdynina, M. M. 1967. CRITICAL TEMPERATURES O CIRCULAR SAWS. Les. Zh. 10(5): 116-121.
Some results from theoretical studies still in progress.

FRICTION

McKenzie, W. M. 1967. FRICTION IN WOOD CUTTIN Forest Prod. J. 17(11): 38-43.
The effects of such cutting variables as pressure, contact are sliding speed, surface roughness of tool, wood species, gra direction, and moisture content are briefly discussed (detail results are to be published later). The author reviews previo analyses of friction in wood cutting.

McKenzie and Karpovich. 1968. (Properties of Wood)

RESEARCH INSTRUMENTATION AND TECHNIQUES

Anonymous. 1967. (Properties of the Cutting Edge and Cutter; Stability)

Anonymous. 1968. BAND SAWS PHOTOGRAPHED. Forest Ind. 95(3): 104-105.
High-speed photographs helped in solving sawing problems.

Barz and Munz. 1968. (Properties of the Cutting Edge and Cutter; Fitting and Sharpening)

Cowling and McKenzie. 1969. (Properties of the Cuttting Edge and Cutter; Fitting and Sharpening)

Hefty, F. V., and Brooks, J. F. 1968. PORTABLE APPARATUS FOR MEASURING SURFACE IRREGULARITIES IN PANEL PRODUCTS. USDA Forest Serv. Res. Note FPL-0192, 3 pp. Forest Prod. Lab., Madison, Wis.
Describes an apparatus for measuring vertical deformations on wood surfaces by a shadow-casting technique. A low angle slit of bright light is directed at two wires to cast sharply defined shadows on the surface. The shadows, viewed perpendicular to the surface, provide a magnified picture of the vertical distortations of the surface at that point. A fixed-focus camera with a 3-inch, wide-angle lens records the surface. The self-contained apparatus can be used on horizontal or vertical surfaces and in any lighting. Six photographs taken at a 1-to-5 slope are presented to illustrate the sensitivity and application of the instrument.

Hoadley, R. B. 1968. IMPROVED TECHNIQUE FOR MEASURING KNIFE CHECK EFFECT ON ROLLING SHEAR. Forest Prod. J. 18(8): 18-19.
Describes a modification of the standard glueline block shear test used to study rolling shear in veneer. Sample preparation is similar to that for the standard glueline block shear test (ASTM D 907-64), except that a layer of veneer is placed between two outer maple pieces; the grain of this layer is perpendicular to the direction of loading. Multiple specimens may be cut from an assembled blank and then "notched" on diagonally opposite corners with saw kerfs extending through the veneer layer to produce either opening or closing of checks during loading. When 1/8-inch veneer is being tested, loads may be applied with the standard ASTM test jig.

Jarrett, K. M. 1969. VIBRATION—THE KEY TO MACHINERY CONDITION. Pulp and Pap. Mag. Can. 70(C): 127.
Discusses the use of electronic vibration on analyzers to det machine disorders as part of a planned maintenance progra By comparing the frequency and amplitude of machine vib tions to the pattern of vibration caused by known sourc equipment malfunctions can be detected far in advance of t usual danger signs of heat and noise. Disorders that can detected include rotational imbalance, mechanical loosene misalignment, and worn bearings.

Ljuboslavsikij, V. D., and Jurcisko, V. N. 1967. ELECTR DYNAMOMETER FOR RECORDING THE COMPONENTS OF T CUTTING FORCE IN ROTARY CUTTING. Les. Zh. 10(5 105-110.
A description of the dynamometer, giving circuit diagrams a drawings.

McKenzie, W. M. 1969. APPLYING GRID PATTERNS WOOD SURFACES USING PHOTOSENSITIVE LACQUERS. Fo Prod. J. 19(2): 43-44.
Describes a procedure for obtaining quantitative data on stra associated with penetration of a cutting edge into wood. T dry wood surface is first sanded on a glass plate with suc sively finer carborundum papers down to 600-grit, then coa with a thin, two-part white epoxy paint. After it has cu at 75 to 80° F. for 1 week, the surface is resanded wit fine paper and a second coat is applied. A photosensi lacquer is then flowed onto the prepared surface. After dry a negative transparency having a grid pattern of the des mesh size is placed in close contact with the surface and photosensitive lacquer exposed with a quartz-iodine l or by sunlight. Developer is then applied to dissolve unexpo parts of the lacquer; the remaining net of lacquer is sta with a black dye and the surface thoroughly dried. Obse tion of gridline deformations during cutting are useful for mating the level and distribution of strains when woo orthogonally cut at slow speed.

Sannikov, A. A. 1968. USE OF THE INA-3 INSTRUM FOR MONITORING THE TENSIONING OF FRAME SAWS ON BASIS OF THE FREQUENCY OF THEIR NATURAL OSCILLATI Les. Zh. 11(3): 77-80.

Schmidt, R. E., and Herbert, R. 1968. DEVELOPMENT O TORSIONAL DYNAMOMETER. USDA Forest Serv. Res. I

INT-82, 11 pp. Intermountain Forest and Range Exp. Sta., Ogden, Utah.
Describes a photoelectric torsional dynamometer for measuring the power requirements of rotating machinery. The design provides for signal generation and transmission without physical contact with the shaft (i.e., no slip rings). The dynamometer can measure r.p.m., and its load range may be varied. It incorporates a slender aluminum alloy shaft mounted in its own bearings and having a 10-inch serrated disk affixed to each end. The periphery of each disk contains 60 evenly spaced notches, 0.25 inch deep. The disks interrupt a light beam passing between each of two sets of lights and photodiodes, producing two interrupted light patterns, which are then converted into a d.c. voltage pulse. Angular displacement of one disk relative to the other produces a phase shift in the pulse patterns. Electronic sensing of the shift generates a constant d.c. output proportional to the phase shift and to the shaft torque. Pulse frequency from one disk is a direct indication of the shaft rotational speed.

Sugihara, H., and Okushima, S. 1968. TEMPERATURE MEASUREMENT OF WOOD CUTTING TOOL USING THE INFRA-RED RADIOMETRIC MICROSCOPE. Wood Ind. 23(8): 10-13, 19-22.

Zajev, N. A. 1968. MEASURING THE TEMPERATURE AT THE CUTTING EDGE OF CIRCULAR-SAW TEETH. Derev. Prom. 17(4): 15.
Describes a thermocouple arrangement for measuring temperatures close to the cutting edge. A few results are given for saws cutting particleboard.

NOMENCLATURE

Anonymous. 1968. SPECIFICATION FOR WOODWORKING MACHINES. I. COMPONENTS. Brit. Stand. BS 4361, 10 pp.

Anonymous. 1969. SPECIFICATION FOR WOODCUTTING BANDSAW BLADES. Brit. Stand. BS 4411, 20 pp.
The standard relates to the terminology, manufacture, properties, dimensions, and tolerances of both narrow and wide bandsaw blades. An appendix gives tables in inch units, equivalent to the metric tables in the text.

Bessonova, N. M., and Cuhlo, V. M. 1969. THE SOVIET STANDARD 'SURFACE ROUGHNESS OF WOOD'. Derev. Prom. 18(1): 9-11.
Describes studies on oak, beech, birch, fiberboard, and particleboard in connection with the revision of the Soviet standard dealing with surface roughness of wood and its measurement.

MACHINABILITY OF LUMBER AND PARTICLEBOARD

Anonymous. 1969. (Sawing; Circular Sawing)

Baum, V. G. 1968. THE 'OMEGA' AUTOMATED SLEEPER-CUTTING UNIT. Lesnaya Prom. (8): 7-9.
Describes a Soviet unit capable of producing 612 sleepers per 7-hour shift.

Brackley, A. M. 1968. AN INVESTIGATION OF THE YIELD OF ROTARY-CUT VENEER AND PLYWOOD FROM EASTERN SPRUCE UNDER SELECTED CONDITION OF MANUFACTURE. M.S. Thesis. Univ. Maine, Orono.

Fukui and Kimura. 1968. (Sawing; Circular Sawing)

Hallock. 1969. (Sawing; Circular Sawing)

Juvonen, R. 1969. SMOOTHNESS OF THE SURFACE OF SAWN GOODS. Paperi ja Puu 51(4): 363-367.

Kerbes, E. L. 1969. NARROW KERF, ACCURATE SAWING: KEY TO HIGHER LUMBER RECOVERY. Can. Forest Ind. 89(3): 76-79.
A British Columbia Central Interior sawmill has a lumber recovery factor of 8.5 board feet per cubic foot when sawing decking from logs averaging 8.2 inches top diameter. When dimension lumber is sawn, 9.1 board feet are recovered from logs averaging 12.7 inches top diameter. Production rate for the bandmill was in excess of 1,500 board feet per man hour. This degree of efficiency was attributed to accurate sawing, narrow kerfs, proper filing, adequate supervision, and employee education.

Koch, P. 1968. STRAIGHT STUDS FROM SOUTHERN PINE VENEER CORES AND CORDWOOD. Forest Prod. J. 18(3): 28-30.
Southern pine veneer cores were converted to 8-foot studs by seven alternate processes. Strength of studs from all processes proved more than adequate for loads normally imposed. The most promising and economical process consists of center-ripping the green core, blanking out a stud from each half-core on a chipping surface-edged, kiln-drying the oversized blanks, and then removing all drying distortions by face-jointing followed by thicknessing and straightline ripping. Prototype studs (two per core) were 100-percent SPIB Stud grade and better. The process also is applicable to 8-foot bolts of southern pine (and perhaps lodgepole pine) in diameters ranging from 5¼ to 6¾ inches inside bark. If a finger joint is made at midlength of each stud blank, the system can be applied to 4-foot-long southern pine cordwood in diameters ranging from 4¼ to 6¾ inches inside bark.

McMillan, T. A. 1968. OPERATION ANALYSIS OF AN ALABAMA LUMBER MANUFACTURING PROCESS. M.S. Thesis. Auburn Univ., Ala.
In a systems analysis of a southern pine lumber manufacturing operation, the marginal log was eliminated and sawing patterns were revised to improve utilization of existing mill machinery.

Maldonado, E. D., and Boone, R. S. 1968. SHAPING AND PLANING CHARACTERISTICS OF PLANTATION-GROWN MAHOGANY AND TEAK. USDA Forest Serv. Res. Pap. ITF-7, 22 pp. Inst. Trop. Forest., Rio Piedras, P.R.
Tests were conducted on plantation-grown Swietenia macrophylla *and* Tectona grandis *from Puerto Rico and* S. mahagoni *from the U. S. Virgin Islands and for comparison, forest-*

grown S. macrophylla *from Mexico, Honduras, and Peru,* T. grandis *from Burma,* Liquidambar styraciflua *from the U.S. and* Betula alleghaniensis *from Canada.* S. mahagoni *proved superior in shaping and planing properties to all other woods tested. In shaping, plantation-grown* S. macrophylla, S. mahagoni, *and* T. grandis *yielded surfaces as good as the imported forest-grown material. All the mahoganies had good planing properties; torn grain in planing was most severe in plantation-grown* T. grandis *but otherwise results for plantation and forest material were similar. Shaping quality was only weakly correlated with specific gravity and growth rate.*

Melichar, J. 1968. THE COMPUTATION OF SAWBLADE SPACINGS AND YIELDS IN SAWMILLING PRODUCTION WITH THE AID OF A COMPUTER. Drevo 23(7): 238-239.

Melichar, J., and Vejmola, S. 1968. ALGORITHM FOR DETERMINING SAWING SCHEDULES AND OUTPUT OF CANT SAWN TIMBER. (BASIS FOR WRITING A COMPUTER PROGRAM.) I. Drevarsky Vyskum 1: 37-49.
Presents a mathematical model that can be computer-programmed to provide various sawing schedules. Decisions are based on the quantity and diameter classes of saw logs, the quantity and dimensions of boards required, and kerf width and blade settings.

Melichar, J., and Vejmola, S. 1968. ALGORITHM FOR DETERMINING SAWING SCHEDULES AND OUTPUT OF CANT SAWN TIMBER. (BASIS FOR WRITING A COMPUTER PROGRAM.) II. Drevarsky Vyskum 2: 103-112.
Additional mathematical formulae are developed to account for square-edged lumber and shorts, waney-edged boards and slabs, and milling waste.

Nanasawa, N., and Koga, T. 1967. CUTTING OF LUMBER CORE PLYWOOD COATED WITH POLYESTER BY CARBIDE TIPPED SAW. Wood Ind. 22(11): 23-25.

Nguen. 1968. (Sawing; Sash Gangsawing)

Pease, D. 1969. CHIP, STUD MILL PROCESSES SMALL LODGEPOLE STEMS. Forest Ind. 96(12): 92-93.
Briefly describes a sawmill converted into a stud and chip mill for handling small, low-grade lodgepole logs. The band headrig was replaced with a two-saw scrag mill, and a roundwood chipper was added. Budgeted production on two shifts is 25 million board feet of studs per year.

Petrovskij, V. S. 1968. ALGORITHMS FOR THE CROSS-CUTTING OF STEMS INTO SAWLOGS, AIMED AT THE MAXIMIZATION OF THE YIELD OF EDGED TIMBER BY VOLUME. Les. Zh. 11(4): 122-126.

Priest. 1968. (Boring, Routing, and Carving)

Reynolds, H. W., and Gatchell, C. J. 1969. SAWMILL SIMULATION: CONCEPTS AND COMPUTER USE. USDA Forest Serv. Res. Note NE-100, 5 pp. Northeast. Forest Exp. Sta., Upper Darby, Penn.
Product specifications were fed to a computer so that the yield from one sample of logs could be determined for several simulated sawing methods. Variation among log samples was thus eliminated.

Rogers, M. T. 1967. SAWMILL RECOVERY DETAILS. Timber Trades J. 263(4752): 63, 65.
Output, costs, and return (1964 prices) from a day's sawing at the Novobord sawmill in Britain are compared with those from comparable operations in Finland. Conversion of 7 Selected Category IV (Forestry Commission) pine logs c taining 2,363 Hoppus feet outside bark yielded 52.3 perc sawn timber (with 5 percent shrinkage allowance) and 3 percent slabwood. The slabwood was chipped and suppl to a particleboard mill. Loss of log volume in sawdust 17.3 percent. Profitability is hinged on the sale of slabwood.

Roscin, N. P. 1968. INDICES OF THE EFFICIENCY OF D FERENT SAWLOG BREAKDOWN METHODS. Lesnaya Prom. (1 28-30.
Five methods of framesawing are compared with respect seven economic indices.

Schumann, D. R., and Pillow, M. Y. 1969. EFFECT TENSION WOOD ON HARD MAPLE USED FOR MANUFACTUR PARTS. USDA Forest Serv. Res. Pap. FPL-108, 8 pp. For Prod. Lab., Madison, Wis.
Cuttings from hard maple containing tension wood ten to warp and to shrink more than cuttings that did not cont tension wood. A high percentage of poorly machined specim was obtained from severely leaning trees and from ba warped samples; this was more pronounced when the sam came from the upper side of the tree, where tension wood concentrated. The authors conclude that cuttings from upper side of severely leaning trees—in excess of 3 degree are likely to behave adversely in applications requiring hi quality cuttings, for example, exposed furniture parts and tr

Tobin, L. R., and Bethel, J. S. 1969. VENEER RECOVE PREDICTION AND ANALYSIS THROUGH COMPUTER SIMU TION. Wood and Fiber 1(2): 97-107.
An analytical procedure features a simulation model to evalu grade recovery and yield in the manufacture of rotary veneer. Data on green veneer characteristics were transfer from photographs to digital form and a program was de oped to simultaneously evaluate veneer recovery in two, th or four grades, using these characteristics as data input. Th major variables—grade requirements, sheet widths, and c ping specifications—could be manipulated, and their ef on yield could be evaluated by reprocessing the same under different conditions. Results of trial runs are inclu to demonstrate several applications of the program.

Tsolakides, J. A. 1969. A SIMULATION MODEL FOR I YIELD STUDY. Forest Prod. J. 19(7): 21-26.
A computer was used to study, on a single log, the gr and volume yields derived from several methods of saw The model consists of a primary program and three sup mentary subprograms (sawing of lumber, rotation of the into a new position, and production of cants). Provision 1/8- or 1/4-inch kerf was included for simulation of circu band, or gangsawing. The size, board-foot content, and l tion of defects were obtained for each board. Limitations the model include lack of full taper removal and inabilit show the depth of defects.

Wu, C. Y., and Huang, Y. S. 1968. STUDIES ON PLAN MACHINABILITY OF WOOD. I. EFFECTS OF THE KNIFE CUTTERHEAD ON QUALITY OF FINISH AND POWER C SUMPTION. Taiwan Univ. Exp. Forest Tech. Bull. 59, 33
Three knives produced a better finish than one knife, required about 30 percent more power.

BIBLIOGRAPHIES

Anonymous. 1968. DIRECTORY OF DEBARKING MACHINES. FAO, 38 pp. Rome.
Briefly tabulates specifications (including price and capacity) of 145 barking machines now being produced by 47 manufacturers in 10 countries.

Koch, P. 1968. WOOD MACHINING ABSTRACTS, 1966 AND 1967. USDA Forest Serv. Res. Pap. SO-34, 38 pp. South. Forest Exp. Sta., New Orleans, La.
Contains abstracts of 326 references arranged by subject matter. An introduction mentions notable papers in various categories and briefly surveys trends in wood machining research. Papers in pertinent categories are cross-referenced and an index of authors is provided.

Koch, P. 1968. WOOD MACHINING HIGHLIGHTS, 1966 AND 1967. Forest Prod. J. 18(9): 65-70.
Brief sketch of advances in wood machining, abrasive planing, veneer cutting, chipping, defibrating, and whole-tree conversion.

Roth, L., and Weiner, J. 1967. BARKERS AND BARKING OF PULPWOOD. 70 pp. Appleton, Wis.: Inst. Pap. Chem.
This first supplement to the original edition (1960) covers the pertinent literature from 1961 to 1966.

Thunell, B. 1968. LIST OF PUBLICATIONS ON BANDSAWS. Swed. Forest Prod. Res. Lab., 28 pp. Stockholm.
Lists 408 publications between 1925 and 1968.

USDA Forest Products Laboratory. 1968. FOREST PRODUCTS LABORATORY LIST OF PUBLICATIONS ON MILLING AND UTILIZATION OF TIMBER PRODUCTS. 30 pp. USDA Forest Serv. Forest Prod. Lab., Madison, Wis.

REPORTS OF RESEARCH PROGRAMS AND INDUSTRIAL DEVELOPMENTS

Anonymous. 1968. (Machining with Coated Abrasives)

Anonymous. 1968. WHAT THEY'LL BE SHOWING AT THE JAFM FAIR. Ind. Woodworking 20(8): 10-19, 30.
Describes new wood-working machinery and equipment exhibited at the National Association of Furniture Manufacturers' Second Annual International Woodworking Machinery and Supply Fair.

Dickson. 1968. (Sawing; Shearing)

Ferguson. 1968. (Machining with Coated Abrasives)

Fientes. 1968. (Defibrating)

Johnston. 1968. (Sawing; Shearing)

Jones. 1968. (Defibrating)

Kask, R. A. 1968. DEVELOPMENTS IN REFINER GROUNDWOOD. Pap. Technol. 9: 489-497.
Significant contributions have been made to the refiner groundwood process since its development. The ribbonlike fibers produced by the refining action account for the substantially higher strength of this pulp as compared to stone groundwood. Usually, most of the refining is done at consistencies in the range of 15 to 25 percent. At present, there is no set rule about the number of refining stages, the power that should be applied, or the consistency to be used in each stage. Pulp samples taken directly from the refiner should be subjected to a hot water disintegration process if the results of laboratory tests are to be comparable with those in a commercial mill. Treatment before refining substantially improves pulp quality of certain wood species. For example, pulp strength and brightness improve when Japanese larch chips are pressed with a small amount of sodium sulfite prior to refining. The refiner groundwood process has made it possible to utilize certain wood residues such as shavings and sawdust.

Page, M. W. 1968. LATEST DEVELOPMENTS IN SAWMILLING EQUIPMENT AND TECHNIQUES FOR SMALL LOGS. Australian Timber J. 34(10): 90, 94-95, 97-99.
Hardwood logs of 5-foot and less girth and softwood logs less than 3 feet in girth are considered small for sawmilling purposes. In many regions the percentage of small logs is increasing, and it becomes important that sawmilling equipment recover high grades at fast rates, while allowing some flexibility in choice of sawing patterns. The ability to tapersaw probably is advantageous. A new method has also been proposed for assessing the capacity of sawing machines. It employs average sawn surface area produced by the machine per unit time and also takes production accuracy into consideration. Three types of "small log" machines are seen in Australia: (1) log edgers with variable saw spacing, (2) high-speed gang framesaws, and (3) riderless pony carriage saws. Small logs increase the frequency of loading and turning; to insure maximum effective sawing time, these operations must be performed rapidly. By the sawn-area criterion, single-cutting pony carriages cut at about the same rate as log edgers, but at only 65 percent the speed of gang framesaws. However, pony carriages permit much wider choice in production techniques. The combination of a double-cutting bandsaw and a pony carriage offers an exceptionally high average sawing rate, coupled with maximum flexibility in choice of sawing patterns.

Sointu. 1969. (History and General Texts)

Trevelyan. 1969. (Defibrating)

Underhay. 1968. (Defibrating)

PATENTS

Artiano, A., and Lindberg, V. L. 1969. WOOD-CHIPPING KNIFE. (U.S. Pat. No. 3,421,561.) U.S. Pat. Office, Wash., D. C.
This invention relates to chippers having a rotary frustoconical housing with a series of knives mounted in a spiral pattern on the interior surface so that they project inwardly from openings in the housing wall. Thus, chips are thrown out through the openings. The knives are designed so that they can be simply made from flat metal stock by stamping or drop-forging and are inexpensive enough so that they can be discarded when dull. Each knife has two cutting edges, one for splitting the wood to the desired thickness, the other for cutting the wood across the grain to form chips of uniform length.

Beloit Corp. 1968. PULPING METHOD. (Brit. Pat. No. 1,116,940.)
Describes a disk refiner whose plates have a special pattern for prebreaking, intermediate, and final fiberizing. The chips are distributed uniformly throughout the prebreaking zone, which is vented to the atmosphere. Steam formed near the inlet of the refiner can escape, thus preventing nonuniform feeding of chips and power fluctuations.

Busch, T. N. 1968. APPARATUS FOR DE-LIMBING TREES. (Can. Pat. No. 784,514.)

Eklund, H. J. 1968. WOOD CHIPPER. (U. S. Pat. No. 3,410,495.) U. S. Pat. Office, Wash., D. C.
Various improvements are claimed for a chipper described in U. S. Pat. 3,276,700.

Hamilton, D. D. 1968. LOG-PROCESSING MACHINE. (Can. Pat. No. 792,051.)
The patent describes a self-propelled machine for processing trees at the felling site. The apparatus includes a delimber, a barker, and a bolt cutter. A boom-mounted device is provided for picking up felled trees and directing them into the machine.

Heermann, R. 1966. HAND APPARATUS FOR DEBARKING OF LOGS. (Ger. Pat. No. 1,215,344.)
The motor-driven portable debarker claimed in German patent 1,207,597 is modified so that the operator is protected from motor vibrations.

Jones, H. W. H., and Helleur, D. E. 1968. PROCESS FOR MAKING A MECHANICAL PULP FROM WOOD CHIPS. (U.S. Pat. No. 3,372,879.) U.S. Pat. Office, Wash., D.C.
Describes a disk-refining process involving separation of the refined material into a primary acceptable fraction and a nonacceptable fraction. The latter fraction is divided into a coarse and a less-coarse portion, and each portion is refined separately. The resulting pulps are combined and separated into a secondary acceptable fraction and a primary reject fraction. The primary and secondary acceptable fractions are then combined to form the final furnish.

Jones, H. W. H., and Helleur, D. E. 1968. PRODUCTION OF MECHANICAL PULP FROM WOOD CHIPS. (U.S. Pat. No. 3,411,720.) U.S. Pat. Office, Wash., D.C.
Describes a machine with two rotating disks that cause the material to flow in a sinusoidal path. The rate of fiber discharge may be controlled so as to increase the amount of specific refining energy. Heat generated in the refining zone is retained to make steam, which may be used to control atmospheric pressure between the disks. The pulp is fractionated and rejected material is reprocessed.

Koch, P. 1969. METHOD FOR PRODUCING STUDS FROM CORDWOOD AND VENEER CORES. (U.S. Pat. No. 3,443,612.) U.S. Pat. Office, Wash., D.C.
The patent describes the production of straight, kiln-dried 2- by 4-inch studs from 4- or 8-foot-long southern pine cordwood or veneer cores. Studs are 8 feet long and of SPIB Stud grade. A primary aim of the process is to utilize raw materials normally destined for pulp chips.

See Koch, 1968. (Machinability of Lumber and Particleboard

Larson, R. W., Olson, O. E., Harkness, W. D., and Mair, W. I. 1968. APPARATUS FOR DELIMBING AND FELLING TREES (Can. Pat. No. 778,179.)

Leider, D. K., and O'Brien, R. E. 1968. DEBARKING APPARATUS. (U.S. Pat. No. 3,417,796.) U.S. Pat. Office, Wash. D.C.
Describes a drum debarker that controls the rate of discharge of debarked logs, thereby controlling the dwell time of the logs in the drum.

Mitten, L. A., and Runnion, E. E. 1968. CUTTER HEAD WITH SLIDE-MOUNTED CHIP-COLLECTING DUCT. (Can. Pat. No. 777,578.)
Describes a device for removing wood from a log so as to produce a cant and pulp chips. The cutterhead is swingably mounted and the chip-collecting chute is designed to maintain a gap of fixed width between the infeed lip of the chute and the cutting plane of the head.

Thomas, K. V. 1968. REFINING APPARATUS. (U.S. Pat. No. 3,371,873.) U.S. Pat. Office, Wash., D.C.
Describes a disk refiner having a frame to which components can be assembled for processing various raw materials. The patent claims the machine can maintain proper alignment and spacing between the refining surfaces.

Wright, J. H. 1968. REFINER SYSTEM. (Can. Pat. No. 775,876.)
The system, including a shredder, a disk refiner, and a screw conveyor, is similar to that described in U.S. Pat. 3,273,80

Yli-Paavola, A. J., and Tampella, O. 1968. DEVICE FOR CONTROLLING THE REFINING LOAD OF A DISK REFINE (Can. Pat. No. 788,203.)
In this refiner, clearance between two disks is maintained by pressing the disks against each other. It is claimed that refining energy may be maintained at a constant value regardless of variations in consistency, wood quality, or feed rate of the stock.

Yock, L. M. 1968. MACHINE FOR CHIPPING CORE LOGS AND VENEER. (U.S. Pat. No. 3,415,297.) U.S. Pat. Office, Wash., D.C.
The apparatus is designed for converting veneer cores and scrap veneer into uniform pulp chips. It consists of a disk cutter having a stop which projects from the surface of the disk towards the edges of knives. Cores enter the disk and contact the stops, which limit the bite of the knives. Veneer is injected at a different angle and the full bite of the knives is used.

SAFETY, INCLUDING NOISE

nonymous. 1967. BLOCK THAT NOISE! TRY EARMUFFS. ulp and Pap. 41(37): 58.
escribes a brand of earmuffs designed to allow the wearer hear conversation (sounds in the range of 500 to 2,000 cles per second) but to block high-frequency and high-tensity noise that may damage the inner ear.

nonymous. 1968. (Properties of the Cutting Edge and utter; Fitting and Sharpening)

nonymous. 1969. (Sawing; Chain Sawing)

xelsson, S. A. 1968. ANALYSIS OF VIBRATIONS IN POWER AWS. Studia Forest. Suecica 59, 47 pp. Roy. Coll. Forest., ockholm, Sweden.
escribes the effects of power-saw vibrations on fingers and ands and states limits of tolerance. Causes of vibration, as ell as physical and theoretical aspects of vibration, are dis-ssed. Improved designs are suggested to reduce the risk injury.

izevskij, M. P., and Skalenko, I. G. 1968. EXPERIMENTS N NOISE REDUCTION IN PLANERS. Derev. Prom. 17(1): 6-27.

reenwood, J. H. F. 1968. NOISE REDUCING ENCLOSURE OR A PLANER AND MOULDER. Woodworking Ind. 25(11): 9-20.
n enclosure of simple construction and moderate cost was signed with sand as the principal insulating material. It duced noise an average of 22 decibels. With the enclosure is possible to supply air to the exhaust system from outside e shop, thereby reducing plant heating costs.

in'kov, V. P. 1968. ESTABLISHING TECHNICAL STAND-DS ON LIMITATION OF THE NOISE OF WOODWORKING ACHINES. Derev. Prom. 17(9): 11.
Iscusses Soviet Standard GOST 11870-66, which delineates ithods of measuring noise, noise characteristics that can measured, and choice and placement of measuring equip-nt.

ayama, S., and Sugihara, H. 1968. ON NOISE ANALYSIS C A BANDSAW MACHINE. J. Jap. Wood Res. Soc. 14(3): 1)-147.
Sound levels and one-third-octave bandpass levels were measured on a 1,050 mm. bandsaw with light-duty automatic carriage. During cutting, average sound levels rose about 10 decibels above the no-load level. Increasing the feed speed increased sound levels in the no-load condition but had no effect during cutting.

Kitayama, S., and Sugihara, H. 1969. ON NOISE ANALYSIS OF SINGLE SURFACE PLANER. J. Jap. Wood Res. Soc. 15(3): 87-92.
Rotational speed of the cutterhead, width of wood planed, and location of microphone significantly affected sound levels. Cutting depth, wood thickness, feed speed, and species had little effect.

Klufas, A. J. 1968. REVIEW OF CERTAIN ASPECTS OF PRACTICAL GROUNDING TECHNIQUES. Pulp and Pap. Mag. Can. 69(18): 81-84.
Grounding provides a safe, permanent path for 60 cycles per second faults, lightning surges, and static charges. Since many factors are involved, each grounding system must be designed individually.

Larson, H. 1968. CHAIN SAW SAFETY BASED ON COMMON SENSE. South. Lumberman 217(2704): 260.
Gives rules for operating chain saws, including care and maintenance, fire prevention, and work safety.

Neumann, F. 1968. AIDS AND DEVICES FOR BAND SAWS IN WOODWORKING FACTORIES. Holz (5): 7-14.
A practical account, with illustrations, of safety devices and aids for sawing material of various types.

Schmutzler. 1968. (History and General Texts)

Simson, I. I. 1968. ACCIDENT PREVENTION IN MECHANICAL WOODWORKING. 184 pp. Leningrad: Izdatel'stvo 'Masinostroenie'.
A book covering many aspects of accident prevention.

Sorensson. 1969. (Sawing; Chain Sawing)

Wuttkowski, H. 1968. PROTECTION OF MACHINES AGAINST VIBRATION. Drevo 23(7): 243-245.
Describes methods of measuring vibration, and ways of reducing it.

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Investment Guide

for

Cottonwood Planters

G. F. Dutrow
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Southern Forest Experiment Station
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1970

Investment Guide for Cottonwood Planters

G. F. Dutrow, J. S. McKnight, and S. Guttenberg

Cottonwood plantations offer the forest manager a number of outstanding advantages as an investment alternative. Pulpwood can be raised in less than 10 years, and sawtimber and veneer logs in 20 years. In both volume and value growth per acre annually, cottonwood is exceptional among hardwoods. This paper provides economic analyses of cottonwood planting opportunities in the Mississippi Delta.

Current knowledge is sufficient to enable the investor to plant cottonwood with considerable assurance of success. Further improvements in planting stock and in the technology of establishing and tending the crop are in sight. These developments will reduce costs, increase revenues, and thereby enhance the rate of return for the investor. To keep up with these developments and the market for cottonwood timber, the prospective investor should contact the Southern Hardwoods Laboratory, P. O. Box 227, Stoneville, Mississippi 38766.

The market outlook and production possibilities suggest that all cottonwood likely to be grown can be readily sold. The cottonwood market is related directly to the more general market for hardwood timber. **Timber Trends in the United States**[1] projects a 44 percent rise in the southern hardwood cut from a 1962 level of 7.0 billion board feet to 10.1 billion board feet by the year 2000.

Cottonwood stumpage is particularly easy to sell because of the numerous marketing options. Modern graining techniques allow the species to be utilized for furniture. Magazine papers made from cottonwood provide faithful photographic reproduction, and the whiteness of the wood makes it ideal for matches and toothpicks. The species is preferred for beverage cases and is found in particle board, hardboard, insulation boards, and excelsiors. Other products range from upholstered furniture frames to fine architectural trim.

Cottonwood plantations promise to provide concentrations of timber more attractive to log than typical hardwood stands available in the Delta and thus to enhance these marketing opportunities. The individual cottonwood producer can expect to sell expanded supplies at favorable market prices. A conceivable threefold increase in total cottonwood supplies is not likely to depress stumpage prices. Even at current prices, the investor can expect high rates of return from planting cottonwood on suitable sites.

[1] USDA Forest Service. **Timber trends in the United States.** USDA Forest Resource Rep. 17, 235 pp. 1965.

Cottonwood represents a mere 3 percent of the available timb volume in the Mississippi River Delta—the principal region suita for its growth. Several factors account for this low percentage. Fir the fast growth rates attributed to cottonwood are limited to spec site and moisture conditions. Second, the highly successful efforts the U.S. Corps of Engineers to control the Mississippi River ha greatly reduced the formation of new ground on which most natu stands of cottonwood were once established. Third, large initial capi expenditures are necessary to establish cottonwood plantations. F ally, highly profitable agricultural land uses compete for sites capal of supporting cottonwood. Because of this competition, the expansi of lands devoted to cottonwood production is unlikely to exceed million acres.

Physical Yields

How much pulpwood or sawtimber can cottonwood plantations yiel Until recently, productivity of natural stands was the guide. Resul from cottonwood plantations are sparse, particularly for stands mo than 10 years old.

To utilize the fragmentary data, existing data were synthesize into productivity schedules by site category. The compilations a based on the research efforts of private industry, universities, Stat and Federal Governments, and foreign investigations.

Data sources were sufficient to segregate productivity schedule into three site categories: high, average, and low. High sites a defined as those with indexes equal to or greater than 120 at age 3(average site indexes are equal to or greater than 100 but less than 120 low site indexes are less than 100. Site index is usually computed fo cottonwood at age 30 rather than 50 because growth is rapid an sawtimber size is attained in less than 30 years.

Pulpwood and sawtimber production schedules were assembled fo each of the three sites. Pulpwood output is representative of planta tions set out on a 10- by 10-foot spacing, 436 trees per acre; a 75 percent survival rate, 330 trees, at age 6 was assumed. Sawtimbe yields are based on a 12- by 12-foot spacing, 303 trees per acre. Again a 75-percent survival rate through age 6 (230 trees) was accepted Industrial experience on large scale plantings corresponds closely with this rate. It was assumed, too, that plantations were established in blocks of about 100 acres and that no recommended cultural proce- dures were omitted. Row thinning was planned for stands less than 10 years of age.

Volume estimates shown in tables 1 and 2 were derived by consoli- dating existing data into average values for number of trees per acre,

TABLE 1—Pulpwood rotation yields

Age (years)	Remaining stand: Trees per acre	Remaining stand: Average d.b.h.	Volume cut per acre
	Number	*Inches*	*Cords*
	High site		
6	240	6.3	3.1
9	0	9.0	36.5
	Average site		
6	240	5.4	3.0
9	0	7.8	26.7
	Low site		
6	240	4.5	1.3
9	0	6.5	16.9

TABLE 2—Sawtimber rotation yields

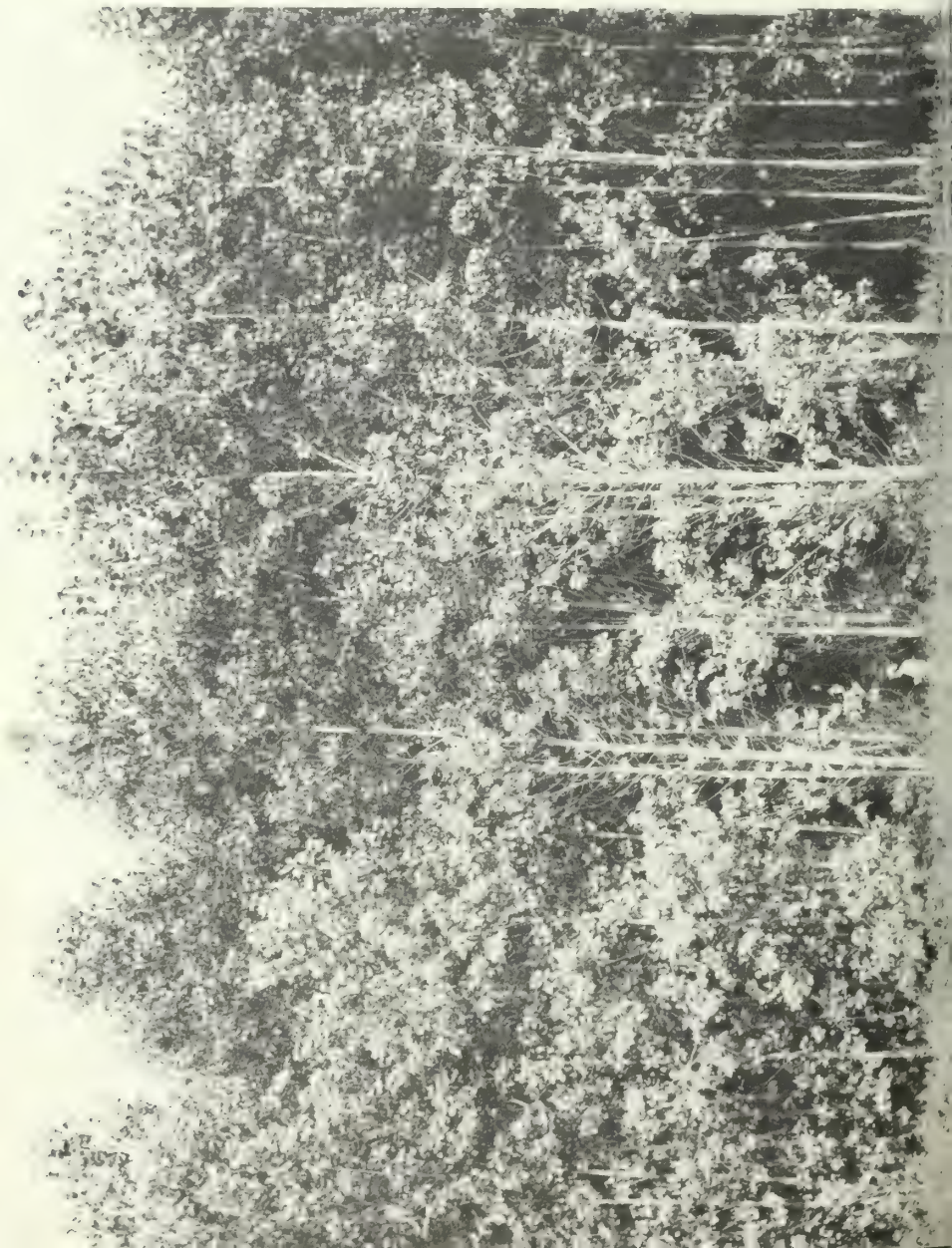
Age (years)	Remaining stand: Trees per acre	Remaining stand: Average d.b.h.	Volume cut per acre	
	Number	*Inches*	*Cords*	*Bd. ft.*
	High site			
6	190	6.5	2.2	. .
9	100	9.1	12.3	.
12	60	12.4	10.0	. . . . .
16	45	16.0	2.0	1,965
20	0	20.0	9.3	14,535
	Average site			
6	200	5.6	1.2	.
9	130	8.0	5.0	
12	90	10.3	7.6	
16	70	13.0	2.2	1,060
20	0	15.2	4.7	7,640
	Low site			
6	200	4.6	.8	
9	130	6.7	3.5	
12	90	8.8	5.3	
16	70	11.4	2.4	
20	0	14.1	3.9	4,900

ieneter at breast height, basal area per acre, and merchantable vol-
m in cubic feet, cords, and board feet. Total merchantable volume,
ncluding thinnings, and mean annual increments were compiled in

cubic feet and cords for ages 5 through 24. Representative values
extracted and are depicted in the tables.

The production levels in tables 1 and 2 are well within the extr
recorded in the data. Maximum mean annual increments on high
ranged from 3.6 to 6.2 cords per acre. The maximum mean an
increment in the tabulation is 4.4 cords per acre, a conserv
figure compared to the best industrial and foreign experiences (fig

Figure 1.—*At age 4 these trees averaged 6.2 inches d.b.h. and 56 feet tall—b
growth than reported in table 1.* **Photo courtesy of Crown Zellerbach Cor
tion.**



awtimber production in table 2 of 14,535 board feet (Doyle rule) t age 20 lies between a low of 5,700 board feet and a high of 30,000 oard feet reported by industrial managers.

Mean annual increments in cubic feet were also computed. For -year rotations, they are 329 cubic feet for high sites, 215 for average ites, and 152 for low sites. Mean annual increments in 20-year otations for the three site classes are 324, 209, and 140 cubic feet er acre. A conversion factor of 75 cubic feet of wood per cord is sed throughout this paper.

Setting the rotation for pulpwood at 9 years and for sawtimber t 20 years was somewhat arbitrary. Two guides to rotation age were dopted. First, the rotations should approximate those advocated by dustrial forest managers with the greatest experience in cottonwood ulture. Second, they should nearly equal the ages of maximum mean nnual increments, which are correlated with highest rates of return.

The yields presented are reliable indicators of productivity of cot- nwood plantations. The investor, however, also wants to know what he yield will be worth.

Prices

Cottonwood planted today will be sold in some future market. Merely rojecting today's prices for pulpwood and sawtimber is risky. Market vings may invalidate the investment analysis and provide misleading plications. For this reason, several sets of pulpwood stumpage ices and combinations of pulpwood and sawtimber prices are included the cost-return analysis. The investor thus is able to measure the vestment potential of cottonwood plantations over a range of eco- mic trends. Price anticipations of the prospective planter determine hich of the curves in figures 2 through 5 are appropriate for him.

These prices should not be taken literally as pulpwood and saw- mber stumpage values. In part they represent the major uses of ttonwood and as such offer a convenient label. In reality, they are blend of prices because the size and grade of cottonwood increase ith age. Prices were blended by setting the so-called pulpwood price r the end of a rotation and varying from that time. For example, lpwood worth $4 per cord at age 9 was assumed to worth only 2.68 at age 6. Sawtimber prices were set and adjusted similarly.

As the plantation matures, the average tree diameter and volume allowable cut increase, leading to logging economics and expanding arket opportunities. Wide spacing and relatively uniform tree sizes low for highly mechanized harvesting at reduced costs. Some of he cost benefits accruing from this type operation are passed to the ndowner in the form of higher stumpage prices. A 20-year-old anaged cottonwood stand would have timber suitable for veneer,

factory lumber, pulp, and particle board. Even on a pulpwood rotat at age 9 significant amounts of logs and veneer bolts would available. The forest manager who sought the highest returns his crop would not sell the timber for exclusive production of p or lumber. In selecting a set of prices from among those offered, location of the tract in respect to market alternatives and noti of price inflation should be considered.

Costs and Returns

In addition to physical yields and expected prices, costs of grow cottonwood are primary considerations in determining the investm potential.

Establishment, annual, and periodic costs vary widely. Costs establishment in particular vary with site conditions, equipm availability, and size of plantation. On the basis of questionnai completed by private and public foresters responsible for establish cottonwood plantations, initial establishment costs per acre w found to average:

Site selection	$ 1.00
Site preparation (land clearing, raking, burning, and disking)	75.00
Planting stock	3.00
Planting	12.00
Cultivation	12.00
Insect control	2.20
Trucking	2.50
Total establishment cost	$107.70

These costs are for 100-acre units on forested sites. Establishi plantations on smaller units would incur, in most cases, high average costs.

In the rate-of-return calculations, the initial establishment c was held in reserve because the individual investor can arrive at b estimates for his particular circumstances. His establishment cost the value for entering the charts to determine the appropriate r of return for a cottonwood investment.

Land costs are often included in investment analyses, and t capacity to do so was retained. Land costs can be added to init establishment costs and the sum used for determining rate of retu on total investment. Throughout the Mississippi Delta and other riv bottoms capable of supporting commercial cottonwood plantatio land is generally not for sale. With the possible exceptions of battu

nds and lands subject to frequent inundations, the acreage in ques-on is agricultural land and maintained on a long-term basis by mily and industrial interests. Growing cottonwood is an alternative nd use on portions of large holdings or on acreage withdrawn from griculture because of government policies. Thus the concept of easuring cottonwood returns by including land costs, assuming nat the land could be sold and the capital invested elsewhere, is limited applicability.

In addition to initial establishment costs, estimates of annual, eriodic, and reestablishment costs were made. These values were cluded in the cost-return calculations and are listed below:

Annual costs per acre	
Taxes	$ 0.50
Management	.50
Fire protection	.50
Total annual cost	$ 1.50
Periodic costs per acre	
Mowing (every 4th year)	$ 4.00
Insect protection (every 8th year)	2.20
Sawtimber rotation-pruning	
Second year	15.00
Eighth year	35.00
Reestablishment costs per acre for subsequent rotations	
Site preparation (land clearing, raking, burning, and disking)	$20.00
Planting Stock	3.00
Planting	12.00
Cultivation	12.00
Insect control	2.20
Trucking	2.50
Total reestablishment costs	$51.70

General revenue and cost functions were postulated to account for rying yields, prices, and costs at different times in the production cles. Discounted revenues and costs were then calculated and com-red to establish net revenue as the present net worth of an acre cottonwood. Discount rates were then varied to enable landowners

to examine the results in accordance with their notion of an app
priate rate of interest. Potential investors can scan the graphs
costs and prices applicable to their own circumstances and anticij
tions. The charts enable analysis of investment potential by alternat
means. In some situations, the investor may have firmly in mind
minimum acceptable rate of return for which all necessary fur
will be made available. More often, the investor will have limit
capital to invest in timber and only a rough idea of the rate
alternative uses of capital. Under these circumstances, the cha
should be used to rank investment proposals from the best to t
poorest until funds are exhausted.

Figure 2 portrays present discounted net worths per acre for c
tonwood planted on a pulpwood rotation. The investment potenti
are for wood income on perpetual—or single—series production pla
on high or average sites. Each curve represents an anticipated pu
wood stumpage price. Thus, an investor considering cottonwood
a perpetual crop on a high site can incur establishment costs
$125 per acre and expect a slightly greater than 5 percent retu
on his investment, assuming a pulpwood stumpage price of $4 p
cord. If he expects a price of $6 per cord to prevail, the same est

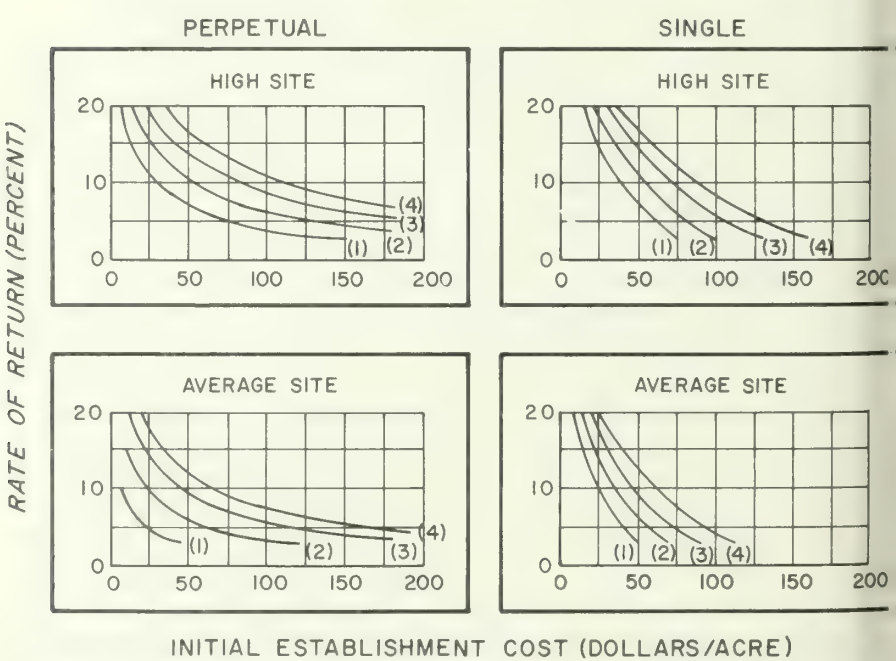


Figure 2. *Rates of return in 9-year pulpwood rotations. Numbers in parenthes
designate assumed stumpage prices: (1) $3.20 per cord, (2) $4.00 per cor
(3) $5.00 per cord, and (4) $6.00 per cord.*

ishment investment will earn in excess of 9 percent. If circumstances ermitted setting cottonwood on previously cleared land, then initial osts of only $55 per acre might be required. This investment com- ined with predicted pulpwood prices of $4 per cord would earn lmost 10 percent. Allowing expected prices to increase to $6 per ord would result in a rate of return on the cottonwood investment h excess of 15 percent.

The expected rate of return falls markedly when site quality eclines from high to average. For example, establishment costs of 125 per acre on an average site would earn only 6 percent in the erpetual series, even under the most favorable price assumption. lere the site sensitivity of cottonwood is underscored. Present net orths for low sites are not presented because normal establishment osts result in returns of less than 5 percent.

In addition to wood income only, computations were made to include unting fees of $1 per acre per year as a further source of revenue. ombined wood and hunting income improves the rate of return shown the figure by approximately 1 percent.

The single rotation series in figure 2 provides a guide for owners ho prefer to commit their land to cottonwood culture for 9 years. armers in particular may wish to take some land out of agricultural roduction for about a decade. Single crops of cottonwood provide n excellent alternative land use, especially where cleared agricultural nd is available on which establishment costs can be cut to $50 to 50 per acre. With these costs, a single pulpwood rotation on a high te will earn, depending on price anticipations, from 6 to 15 percent te of return.

Once again the reader is cautioned on the extreme site sensitivity cottonwood from an economic point of view. With the most con- rvative pricing assumptions, present net worth at 5 percent rate return declines by some $55 per acre when site quality drops om high to average for perpetual pulpwood rotations. Low sites romise financial loss at the same prices. Thus, careful site selection i vital to success in cottonwood culture.

The investment guides presented are not directly applicable to idustrial plantations. Pulping firms currently pay up to $45 a cord r cottonwood delivered at the mill yard. They incur these costs cause cottonwood permits drastic reductions in the cost of bleach- ig. Without cottonwood the firm might be forced to invest heavily t expand bleaching capacity. In this situation, even low sites may rove relatively profitable.

The industrial firm has procurement alternatives ranging from t al reliance on the stumpage market to supplying all cottonwood reds from its own lands. The choice among these alternatives for

obtaining cottonwood must be based on cost-quantity consideration If the cottonwood supply zones can be thought of as concentr circles with the processing plant at the center, procurement optio will be ranked according to delivered prices of given quantities cottonwood from each zone. As rising demand for cottonwood forc stumpage values up, cost considerations require that distant, hig freight, sources be abandoned and cottonwood cultivation be intensifi on strategically located company-owned lands. When these conside ations are analyzed, firms are apt to find that the highest stumpa prices given in this paper are too low for investment planning.

Higher stumpage prices imply a higher value or demand for lan capable of supporting cottonwood. At the same time, the situati warrants bringing some formerly submarginal lands into cultivatio Company lands formerly marginal for cottonwood plantations no become profitable. The value of other productive lands must ri accordingly, and submarginal or low sites become an increasing profitable source of cottonwood for the industrial firm.

Figure 3 represents the present net worths for cottonwood sawtimber rotations. Regardless of the price combination chose

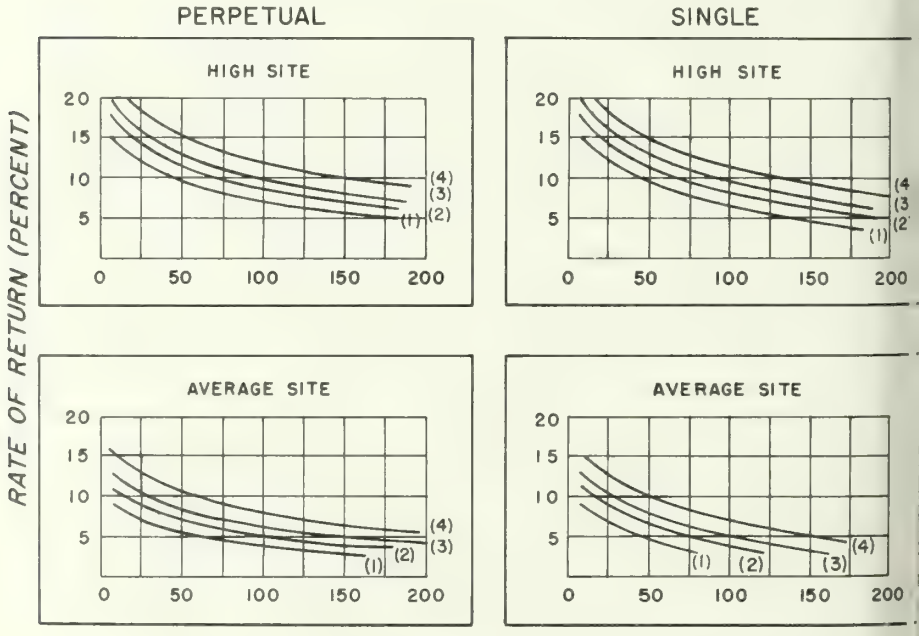


Figure 3.—*Rates of return in 20-year sawtimber rotations. Numbers in pare theses designate assumed future stumpage prices: (1) $3.20 per cord, $24. per M bd. ft.; (2) $4.00 per cord, $30.00 per M bd. ft.; (3) $4.80 per cor $36.00 per M bd. ft.; and (4) $6.00 per cord, $45.00 per M bd. ft.*

ising cottonwood for sawtimber is more lucrative than growing ulpwood alone. This is to be expected, though, in light of current nd anticipated price differentials. An owner who estimates his tablishment costs to be $107 per acre on a high site for perpetual ries can expect a rate of return ranging from 7 to 11 percent, epending on his choice of future prices. On an average site, this vestment would earn from 4 percent to 7 percent.

Single rotation are not as profitable as perpetual series, except a extremely low establishment costs. Low initial costs allow the ndowner who plans a single rotation to earn relatively high rates d interest.

Cottonwood Plus Soybean Income

For individuals that wish to convert depleted hardwood stands t cottonwood, the high initial costs limit the rate of return. One ssibility for reducing the impact of establishment costs is to set ct an agricultural crop, which partially defrays land clearing costs, fr one season prior to planting cottonwood. This procedure lengthens te investment period by 1 year but significantly reduces the initial csts for establishing cottonwood plantations.

Soybeans were selected as the agricultural crop to be grown in te first season. Current net financial returns from soybeans[2] were ct by 30 percent, 44 percent, or 57 percent to reflect site differences ad to compensate for the typical below-par output of new ground i the first year of cultivation. Soybeans were chosen because site rquirements are similar to those of cottonwood and the crop provles favorable net returns.

Net soybean returns include land clearing and preparatory costs tat would normally be charged against cottonwood. Thus, establishnnt costs charged to cottonwood in the second year would approxinte those of reestablishment at rotation's end, or about $55 per acre.

Wood-soybean investment opportunities were calculated for pulpwod and sawtimber rotations, and expected rates of return on this investment option are depicted in figures 4 and 5 for various price asumptions and estimated establishment costs on the three sites. Ce significant change from the wood-only production scheme is that en low sites provide positive rates of return at the high stumpage pces.

n 10-year perpetual pulpwood rotations on high sites where a sbean crop is grown initially, a $55 establishment investment would en from 12 percent to approximately 20 percent rate of return, dpending on the price schedule selected (fig. 4). On an average site,

[2] Imill, J. G., and Woolf, W. F. **Data for farm planning in the Ouachita River Valley area of Lusiana.** LSU Agr. Exp. Sta. DAE Res. Rep. 371, 90 pp. 1968.

with similar production plans, the rate of return would vary fr
4 percent to 10 percent with an equal initial cost. Returns on a l
site would range from 4 to 6 percent if favorable prices prevail
Cost benefits accruing to industry by insuring cottonwood inpu
especially from their own lands, promise to make plantations on th
low sites a profitable venture.

Figure 4 also presents expected rates of return for single pulpwo
rotations with combined wood and soybean income. The landowi

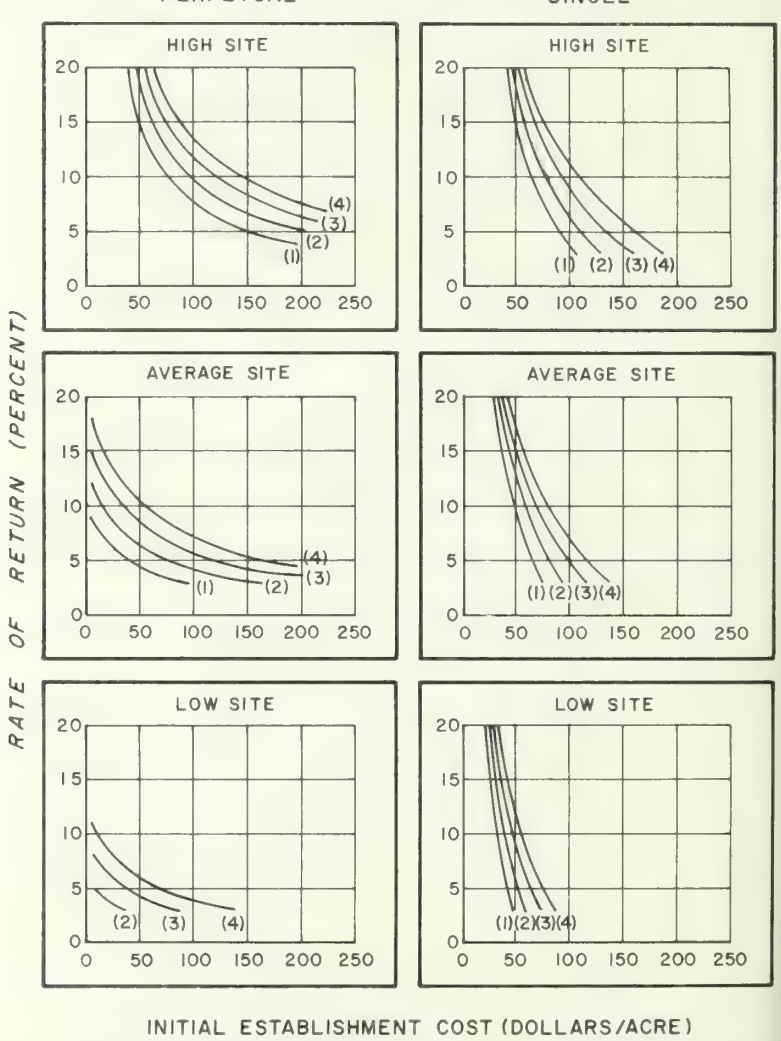


Figure 4.—*Rates of return for 10-year pulpwood rotations where soybeans a
grown for the first year. Numbers in parentheses designate assumed futu
stumpage prices: (1) $3.20 per cord, (2) $4.00 per cord, (3) $5.00 per cor
and (4) $6.00 per cord.*

who faces governmental limitations on crop lands finds a soybean-cottonwood combination very promising. An initial establishment cost of $60 on a high site would earn from 11 to 19 percent rate of return, depending upon prevailing prices. With the same initial costs, the rate of return would range from 6 to 14 percent on average sites and from 3 to 8 percent on low sites.

Figure 5 provides an estimate of the investment opportunities for a combination of cottonwood sawtimber and soybeans in a 21-year

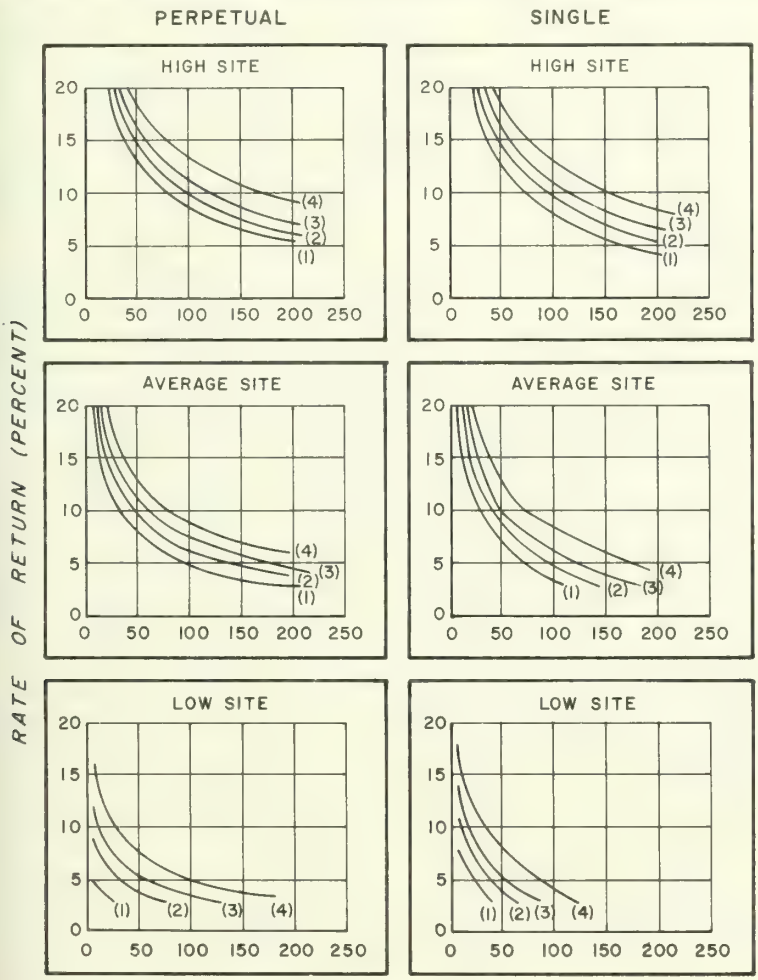


Figure 5.—*Rates of return for 21-year sawtimber rotations in which soybeans are grown for the first year. Numbers in parentheses designate assumed future stumpage prices: (1) $3.20 per cord, $24.00 per M bd. ft.; (2) $4.00 per cord, $30.00 per M bd. ft.; (3) $4.80 per cord, $30.00 per M bd. ft.; and (4) $6.00 per cord, $45.00 per M bd. ft.*

rotation. On a high site, perpetual series, establishment costs of $ per acre should earn from 12 to 17 percent for the various pr combinations. Similar production plans and establishment costs pro ise rates of return of 7 to 12 percent on average sites and up t percent on low sites. Single rotations also provide attractive ra of return, especially with the lower establishment costs result from an initial soybean crop.

Conclusions

Cottonwood returns are favorable relative to other hardwo species. Expansion in acreage allocated to cottonwood appears limi to suitable sites where other hardwoods or agricultural crops currently grown. Shifting land from production of other hardwo species to cottonwood would be beneficial from the standpoint greater wood yields per acre and more intensive management acreage available to forestry.

Greater limitations exist in the transfer of agricultural lands fr crops to cottonwood. Soil requirements for profitable cottonwood p duction are similar to those of cotton and soybeans. To compe with cotton as an equally profitable land use, cottonwood stumpa prices would have to soar to some $30 per cord for a pulpwood ro tion or to a combination price of $12 per cord and $165 per M ft. for a sawtimber rotation. In the case of soybeans, cottonwo prices would have to increase to $13 per cord or combined pri of $6 per cord and $72 per M bd. ft. for pulpwood or sawtimb rotations to provide equivalent rates of return on investments. S stitution of man-made fibers for cotton and inroads by substitu oils into the soybean market should improve the relative positi of cottonwood as an alternative land use. Cottonwood should cla increasing portions of agricultural lands as more farmers choose are induced by government programs to temporarily set aside c lands for alternative uses. Agricultural lands most likely to shift cottonwood are now in soybeans. These lands need to be examir carefully for their suitability, since cottonwood thrives under a n rower range of soil conditions than soybeans.

Cottonwood plantations offer forest managers and forest industr the best single alternative for reversing the decline in forest resour in the Mississippi Delta. The species currently yields high ann outputs of all classes of timber products, and superior planting sto will soon be available. Preliminary tests indicate a 20 percent incre in yield from the superior cuttings. However, there are drawbac associated with the investment potential of cottonwood. It takes lar capital investments to establish and maintain a stand of cottonwo Careful site selection is a must because only the best soils can gr

cottonwood economically. Nonetheless, cottonwood is sold in a market where significant expansion is predicted, while markets for agricultural crops are expected to decline. In the Mississippi Delta, cottonwood should capture a growing share of the hardwood market. The species grows fast, is highly marketable, and may well be instrumental in restoring vigor to the forest economy of the Delta.

Planting Cottonwood Cuttings for Timber Production in the South

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J. S. McKnight

Southern Forest Experiment Station
Forest Service
U. S. Department of Agriculture

1970

Planting Cottonwood Cuttings for Timber Production in the South

J. S. McKnight[1]

Intensive cultural methods developed through research have added cottonwood (**Populus deltoides** Bartr.) to the list of commercially plantable timber species in the United States. Most of this paper is devoted to describing a system for planting cuttings that has proved highly successful in the fertile river bottoms of the South. Where it can be applied, the system offers many advantages. Stem cuttings are easy to handle, and vegetative reproduction permits rapid incorporation of genetically improved material. It should be recognized at the outset, however, that the system described is applicable only where winters are mild and the soil is rich, moist, and well drained. Cottonwood can be grown in other areas, but special planting and cultural methods are required. A concluding section of the paper covers such situations.

This paper summarizes results of past research and reports findings based on new research and experience in both experimental and commercial planting. Procedures are described for choosing and preparing sites, producing planting stock, establishing plantations, and managing the stands through to harvest. Cost of various operations are given, and investment opportunities summarized.

Although eastern cottonwood is best known as a fast-growing shade tree, foresters have been experimenting with plantings for timber production for the last 50 years in the United States. In 1918, for example, the Mead Corporation in Ohio, established a pilot-scale plantation from seedlings **(1).** Satisfactory experimental plantations were established from cuttings by the Southern Forest Experiment Station in the 1940's. Eisenhelder did much of the early work that encouraged pilot-scale planting of the species **(7).** Further impetus was provided when in the early 1960's Crown-Zellerbach Corporation began planting eastern cottonwood on a commercial scale. Since that time, U.S. Gypsum Company, Chicago Mill and Lumber Company, Greif Brothers Cooperage Corporation, Roy O. Martin Lumber Company, Trans-Match Incorporated, Anderson-Tully Company, and others have been adopting results and developing practical methods for establishing and managing large plantations.

Europeans have been including eastern cottonwood in poplar hybrids for about 250 years. In some countries, notably Italy, hybrids that have eastern cottonwood as one parent are grown for pulpwood and saw and veneer logs. A bibliography of **Populus** species and hybrids throughout the world **(3)** is recommended for those interested in hybrid poplar culture.

Anyone preparing to establish a commercial plantation of eastern cottonwood on a southern bottom land should recognize that all the recommendations presented here must be followed. Neglect of any step is likely to lead to failure of the entire operation. If the "package" described here is among the most attractive that a forester can purchase, it is also among the most expensive. It makes no sense to risk loss of the entire investment by attempting to eliminate any of the operations described.

Choice of Planting Site

Cottonwood is a prima donna. Under ideal conditions it performs as no other tree species can. For rapid growth the soil must be well aerated and moist throughout the growing season, and it must contain abundant nutrients. Under these conditions, first-year heights of up to 20 feet can be expected. Cottonwood will survive on most river and stream bottom soils, but it produces handsome returns only on the best sites.

Broad site groups that have been found best for growing cottonwoods are the lands still subject to the natural overflow of the Mississippi River and its major southern tributaries such as the Red, Arkansas, and St. Francis Rivers. Superior sites are also found on outwashes from the fine silts in the Silty Uplands area immediately to the east of the Mississippi Valley and next to Crowley's Ridge in Arkansas.

Cottonwood thrives on well-drained sandy loams and silty loams in most southern river bottoms. Best

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[1] When the data were gathered, the author was on the staff of the Southern Hardwoods Laboratory, which is maintained at Stoneville, Miss., by the Southern Forest Experiment Station, USDA Forest Service, in cooperation with the Mississippi Agricultural Experiment Station and the Southern Hardwood Forest Research Group. He is now Assistant Area Director, Division of Cooperative Forest Management, Southeastern Area, State & Private Forestry.

growth is always where the site is situated to receive ample moisture during the growing season from a water table that is 3 to 6 feet below the surface, from precipitation, or from lateral movement in sandy loams or silty soils next to open water. Cottonwood can withstand flooding if the water is cool and flowing or does not stay on the ground surface for extended periods during the growing season. Ridges that contain deep layers of sand are likely to be excessively dry during rainless periods in the summer.

Unless they are fertilized, soils derived from Coastal Plain material usually do not contain sufficient nutrients for good cottonwood growth. Alluvial soils of the Mississippi River, Blackland prairies, and loess areas, and those primarily from Piedmont, mountain, or Great Plains sources normally contain ample nutrients.

Clay soils are usually not satisfactory for cottonwood plantations. Clays will only support good cottonwood growth if they have ample organic matter and moisture, and if good physical structure is preserved as through plowing occasionally during the life of the plantation.

If a soil survey map is available for land where planting is contemplated, soil series can be used to indicate probable cottonwood growth in the Gulf South.[2] The best growth has been observed on:

Delta
- Commerce
- Convent
- Bowdre
- Bruin
- Latanier
- Mhoon
- Norwood
- Robinsonville
- Bosket

Loess
- Adler
- Collins
- Morganfield
- Falaya
- Vicksburg

Blackland Prairie
- Kaufman
- Marietta

Good growth can be expected on:

Delta
- Amagon
- Coushatta
- Dubbs
- Dundee
- Hebert
- Iberia
- McGehee
- Newellton
- Portland
- Tensas
- Tiptonville
- Tunica

Loess
- Arkabutla
- Memphis
- Natchez
- Rosebloom
- Waverly

Blackland Prairie
- Catalpa
- Houlka
- Leeper
- Trinity
- Verona

Coastal Plains
- Mantachie
- Ochlockonee
- Wehadkee
- Chewacla
- Iuka

Mediocre growth has been observed on:

Delta
- Alligator
- Baldwin
- Beulah
- Buxin
- Forestdale
- Moreland
- Perry
- Roebuck
- Sharkey

Blackland Prairie
- Tuscumbia

Coastal Plains
- Bibb
- Chastain
- Una
- Urbo

On soils where mediocre growth is expected, the investment in a cottonwood plantation usually cannot be justified.

It is wise to have a soil survey made of the area that appears suitable for planting. Soil should be sampled to a depth of 4 feet to provide adequate information for careful site choice (fig. 1).

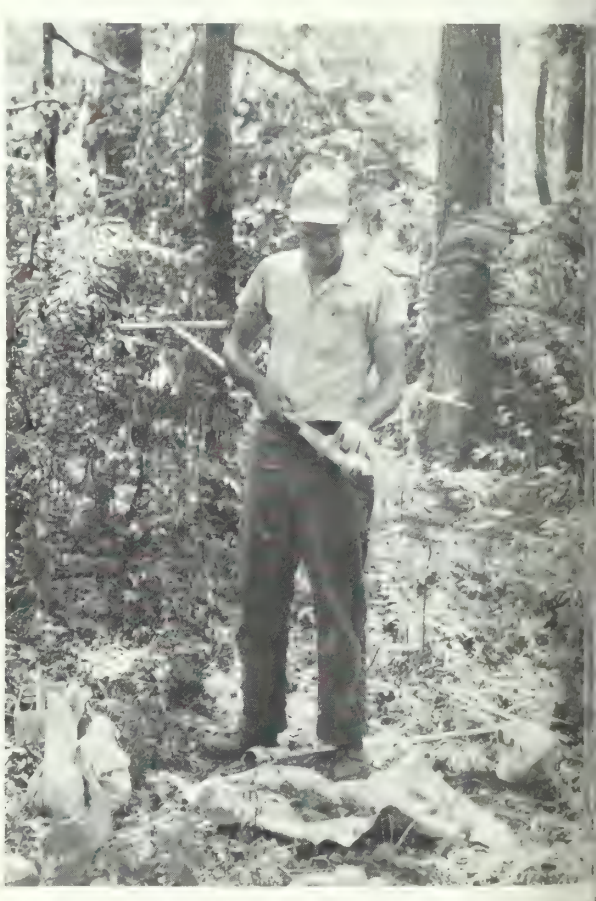


Figure 1.—Soil should be sampled to a depth of 4 feet to get sufficient information for choosing sites.

In addition to soil features, site selection is influenced by accessibility, size of tract, roughness of terrain, susceptibility to flooding, and nearness to all kinds of markets for cottonwood.

[2] Personal communication with Dr. M. Broadfoot, Principal Soil Scientist, Southern Forest Experiment Station, Stoneville, Miss.

Easy access keeps establishment costs down and ses the value of the stumpage produced. Planting of s species requires intensive site preparation prior to nting, and if woodland must be cleared, heavy chinery is necessary. Planting and intensive care er planting require access for men and machinery. cess is also important for both thinnings and final rvests. The more accessible the site, either by water highway, the more likely the plantation is to yield a h rate of return on investment.

A certain minimum size of tract is required to make necessary cultural measures practical. This size will ry somewhat with local conditions, but areas small- than 100 acres should probably not be considered. as been determined that up to 150 acres can be tivated by one tractor during the first growing sea- if the site has been carefully prepared prior to nting. A single tract or several small neighboring cts aggregating this total are needed to keep one ctor and operator busy throughout the growing sea- .

Roughness of terrain is a consideration because of problems that may develop. The first is apparent hose who have used farm equipment. If the terrain oo rough the various operations requiring wheel ctors cannot be performed efficiently. Terrain also is ated to flooding in bottom lands. Depressions in bot- lands that may hold water from river overflow er floods recede will not be suitable for planting of ooted cuttings.

As much as $1 per acre has been spent to properly luate planting sites for cottonwood. In view of the ge investments to follow, the money spent for care- site evaluation is easily justified. It is also important delineate areas to be planted with considerable re- ment before the site is prepared. If areas are ared that cannot be successfully planted, cost per of production will climb accordingly.

Site Preparation

ites which are recommended for planting are in- ently rich, and the climate of the Deep South is itropical. Under these conditions, weeds as well as s flourish, but cottonwood can stand little if any petition for light and moisture, particularly when it ung. Careful site preparation therefore is essential et the trees well established. Also, the better the preparation, the easier is weed control during the summer after planting.

nother critical factor to consider in site preparation il aeration. Although cottonwood will grow on the types listed in the previous section, it will not do if the structure of the soil has been seriously al- through compaction, long-flooding during the growing season, or excessive plowing. Aeration must be restored before successful plantations can be established. Looseness of the soil also allows better absorption of growing-season precipitation.

Experience and research have shown that sites long in field usually need thorough and deep plowing before planting of cottonwood. This plowing breaks the sod, eliminates compaction, aerates the soil, and allows rapid percolation of moisture from rainfall.

On fertile sites, particularly in Mississippi River bottoms, large quantities of Johnson grass **(Sorghum halepense** (L.) Pers.) may be present. This grass must be controlled before planting cottonwood, and the only effective treatment known includes following the year preceding planting. The site should be plowed or deep-disked about July 1, ordinarily the driest part of the growing season, to expose Johnson grass rhizomes to the heat and drying of the sun. Heavy disking or plowing should be repeated at intervals of about 2 weeks until all rootstocks have been exposed and destroyed. Seedlings of this grass will emerge the following spring, and they must be eliminated by cultivation. A seedling of Johnson grass that survives over 3 weeks following seed germination starts a runner which is difficult to kill with spring cultivation. Therefore, even though old rhizomes have been killed, cultivation must be planned as soon as ground conditions will permit following the emergence of the grass seedlings.

Fall application of a preemergence herbicide such as trifluralin or nitralin destroys grass seedlings that emerge the following spring. However, the application of such a chemical is no substitute for cultivation. The treatment is generally unsatisfactory unless applied to extremely well-prepared ground, and it is beneficial mainly on old fields where grass is a major problem. Research thus far has indicated that some cultivation is desirable even when grass and weeds are absent.

If chemicals are used they should be applied in a band about 2 feet wide on each side of the planting row at the time the site is marked for planting. The appropriate rate of application is between 1/2 and 1 pound per acre, and the chemical should be disked into the soil to a depth of less than 2 inches during the fall prior to planting. Chemical cost for this treatment will be approximately $3 per acre.

On some old fields deep plowing is necessary to break up plow soles or pans that have developed through long years of cultivation and traffic. Under such conditions good results have been obtained by plowing to a depth of 16 to 20 inches (fig. 2). Such ground breaking is expensive, about $25 per acre, but it has proven essential for rapid early growth of cottonwood.

Figure 2.— Land that has long been in field or pasture may require deep plowing before cottonwoods are planted.

The most successful plantations are on land recently cleared of timber. Here, soil is in good physical condition and noxious weeds are usually not plentiful. If the site is thoroughly cleaned after the trees are sheared, cultivation of the plantation during its first year of growth can be done at a reasonable cost, and it will be highly successful. Debris left on the site will increase cultivation costs and cause mechanical damage to the young cottonwoods during cultivation.

Plans for clearing the site should be completed at least 2 years ahead of the planting operation to allow time for harvest of all merchantable sawtimber and pulpwood. Both land clearing and site cleaning must be done in dry weather.

Stumps left after logging and unmerchantable trees and shrubs should be cut at or just below the ground surface to avoid moving any of the topsoil. Uprooting of this material is neither necessary nor desirable. Care must be taken, however, to leave no protuberance that will later interfere with planting and cultivation. The sheared material must be windrowed, a job that is best accomplished with heavy rakes mounted on the front of crawler tractors. These windrows must be burned, and remnants must be concentrated and burned during dry weather to reduce the debris to ash.

Deer populations are high in southern bottom-land forests, and leaves and tender growing tips of cottonwood are a favorite food for deer and livestock (fig. 3). Crude fences made from piled debris have proved an effective barrier. They can be prepared by pushing material collected near the outer edge of the clearing to a height of 10 to 12 feet. The base of such barriers will be about 20 feet across. Experience has shown that deer will not cross such fences until the lower branches have deteriorated in a year or two. By this time the cottonwood crowns will have grown beyond the reach of deer.

Figure 3.—Cottonwood sprouts are favored browse of deer.

Roads through the windrow fence are necessary for quipment traffic. They can be gated against deer by ıretching burlap across the openings (fig. 4) **(6).** Cat-e, mules, and horses are more resourceful than deer nd should be pastured away from first-year cotton-vood plantations.

After the site has been roughraked, some planters imply pick up the largest chunks of roots and other ebris. However, dump rakes with closely set spring eeth are recommended to follow the heavy rakes (fig.). After all debris is swept from the soil surface, the rea should be thoroughly disked with a harrow that veighs at least 8,000 pounds if it is 13 feet wide. calloped disk blades should be about 26 inches in iameter and at least 5/16-inch thick. It is usually ad-isable to disk in two directions. Except where there re stumps, the disks should cut into the ground about inches.

An average of 5 acres per day can be expected er heavy tractor unit for shearing, piling, and burn-ıg. These operations require crawler tractors with a rawbar horsepower of at least 140. Subsequent op-rations can be done with heavy wheel tractors hav-ıg a drawbar horsepower of at least 60.

All operations preceding the heavy disking should e completed before September 1. Disking should be ompleted by November. Where feasible this opera-on should be followed by another fine raking, and hunks missed by the rakes should be picked up by and. After the final raking some commercial planters rag the site to clean it and make it as smooth as pos-

Figure 5.—Fine raking to remove small debris speeds cultivation while reducing damage to the small trees.

sible for later machine planting and rapid cultivation. Drags are made from 12- to 20-foot lengths of steel rail.

A good job of site preparation pays off in at least four ways: (1) reduces cost for mechanical planting, (2) avoids mechanical damage to very young trees by debris kicked up by cultivators, (3) cuts cultivation costs, and (4) reduces wear on cultivating equipment. Mediocre site preparation has caused a 10-percent loss of trees through mechanical damage during cultivation. Careful preparation has increased the speed of each cultivation by as much as 20 percent.

ıure 4.—Deer can be excluded from the plantation by making a debris fence. Openings for equipment access can be ted cheaply with burlap.

Costs of land clearing, including shearing, piling, burning, raking, and disking, will vary from $65 to $75 per acre, depending on how well the site is prepared for subsequent operations. Generally, tree shearing is contracted because of the very heavy equipment required. Piling and burning require similar tractors, and these operations are also done by contractors. Disking to adequate depth requires heavy equipment and should be contracted unless the plantations planned are large enough to justify purchase of the equipment that is needed. Fine raking and cultivation are often done by landowners who already own rubber-tired tractors with sufficient power.

Planting Stock

Although either seedlings or cuttings can be used, cuttings are preferred as planting stock in the South. They survive and grow as well as seedlings and are cheaper to procure and plant. On study plots, survival of unrooted cuttings and seedlings did not differ significantly 2 years after planting. Rooted cuttings planted in 30-inch holes had superior survival, but the advantage over unrooted cuttings and seedlings was not large enough to justify this expensive procedure. Cuttings are more desirable than seedlings because genetically superior strains can be expanded most rapidly through vegetative reproduction. Recent tests have proven that improved strains grow to pulpwood size 20 percent faster than other planting stock. Improved plant material for the lower Mississippi Valley is being multiplied through vegetative means and will soon be released for commercial use **(10).** Material is being tested for other areas and it should be available in several years.

Cuttings for commercial cottonwood plantations are being produced in some State and industrial nurseries. Since planting of the species is likely to become increasingly popular, many nurserymen who are unfa miliar with cottonwood may soon find themselves pr ducing cuttings. They can benefit greatly from th experiences of others.

The purpose of the nursery operation is to produc wands which are harvested after one growing seas (fig. 6). The wands, which will be cut into short lengt for field planting, are themselves grown from cuttings

In the nursery, the cuttings should be planted 8 12 inches apart in rows 36 to 40 inches apart (fig. 7

Figure 6.—The nursery's objective is to grow long wan that are relatively free of limbs. The san rootstocks can be used for 3 years before th are replaced. (Photo courtesy Crown-Zellerbach)

Figure 7.—In the nursery, cuttings shou be spaced 8 to 12 inches apa within rows, and rows shou be spaced 36 to 40 inch apart. Good drainage must provided, and the soil shou be kept moist throughout t growing season.

he nursery bed should be fumigated if cottonwood as been grown there previously, and good drainage essential. Where the nursery has a watering system, ttings 10 inches long can be planted. Where no artiial watering system is available, 20-inch cuttings ould be planted. With either length, all but 2 inches the cutting should be firmly placed beneath the soil. ands can be harvested annually for 3 years from the otstocks that are established.

Cuttings of improved clones will soon be available, nd unimproved stock should be planted in nurseries nly when supplies of the improved material are insufient. The source of stock should be no more than 200 iles north or south of the planting site, and preferably om the same latitude or south of it to assure the best e of the growing season. In the past, cuttings were ken from seedlings along riverbars, ditches, and borw pits for nurseries or for stock to be placed directly plantations. Today most commercial planters pro re cuttings from nurseries, and as improved stock ecomes available planters should use it exclusively.

Cuttings from 1-year-old wood in the crowns of ees 4 or more years old are not recommended for eld planting. In tests with such cuttings from the owns of trees 10 to 25 years of age survival was ery poor — 6 to 16 percent **(7).**

When soil conditions are right, the wands produced the nursery may reach heights of 12 to 16 feet in 1 ear. These whips should be harvested only when the ees are completely dormant and just as close to the anting time as practical. Harvesting is often done by and with machetes, but machines are being develbed for large nurseries. The sprouts should be cut bout 2 inches above the ground, pruned, tied in anageable bundles, and placed in fresh-water onds. Some planters bulldoze trenches, drive wells earby, and keep water flowing in these ponds until e whips are to be made into cuttings. Keeping light om the water will prevent development of algae if ttings or whips are stored for short periods in still ater. If the material is to be stored over 2 days, flowg water is essential to provide aeration and to preent growth of algae. In addition, flowing water ashes spores of disease-causing organisms from the ark surfaces and destroys the larvae of the twig bor, which overwinters in bark crevices.

Cuttings can be made from the whips by chopping, ut power sawing whole bundles with a fine-toothed aw is more convenient in large operations. The optium length for field planting in the South is 20 inches. e saws are often operated immediately adjacent to e planting sites to assure freshness of planting stock. nly cuttings from 1/2 inch to 1 inch in diameter ould be used, and split or peeled cuttings should be discarded. Small cuttings dry out excessively after planting and contain too little stored food to give the tree a good start. Cuttings larger than 1 inch are excellent planting stock but are hard to handle. Crooked sections of stem should be discarded, as should stems with cankers or insect emergence holes. Orange-colored pith may show on ends of cuttings when borers have been busy. Waste should be burned regularly.

If the whips are cut into 20-inch lengths in the nursery, they should be stored carefully. For ease of handling and counting, cuttings should be tied in bundles of 100 with all the butt ends pointed in the same direction. Drying and exposure to light for extended periods before planting are very harmful. Cuttings or even whips should not be exposed to drying conditions during transport to planting sites. A tarpaulin or wet burlap will keep the stock in good shape. Prior to planting, cuttings should be soaked in water until they are fully saturated — a process that may require 3 days.

When planting will be delayed until after the start of the normal growing season, cuttings must be kept in cold storage, where the temperature can be maintained between 28 and 32° F. Cold air must circulate around the cuttings to keep them from sprouting. To keep them moist, bundles can be set butt down in a 2- to 3-inch layer of moist sand on wooden duckboards placed over a permanent floor. Each layer of bundles should be covered with burlap which must be thoroughly wet down twice a week.

Costs of nursery stock will vary from $6 to $10 per thousand cuttings. Cost per thousand has been reduced somewhat by commercial planters who have established temporary nurseries in conjunction with first-year plantations. These nurseries are on sandy or silty loams that are moist but have good surface drainage. They are usually next to a river or other body of water. As many as 50,000 cuttings have been produced from 1 acre, but 25,000 is about average. In the winter when the nursery is abandoned, some well-spaced sprouts are left to form the dominant trees in the subsequent "plantation."

Nurseries must be kept free of weeds. Also, insect pests must be kept to a minimum. A systemic insecticide consisting of activated carbon dust with 44-percent phorate is registered for dip-treating cottonwood cuttings at planting. This chemical and treatment can be recommended for the first-year protection of cottonwood nurseries from the cottonwood twig borer **(Gypsonoma haimbachiana** Kearf.) and associated insects. The treatment does not fully protect against the cottonwood leaf beetle and other defoliators near the end of the growing season. In recent studies other systemic insecticides have shown promise. Ultra low volumes of rapidly degradable insecticides show promise

for controlling defoliators without polluting the environment around the nursery. In a field trial, malathion (95 percent Cythion® ULV) applied with a tractor-mounted pressurized mist blower at 14 ounces actual spray per acre gave complete control of the cottonwood leaf beetle. An 8 ounce per acre application of Dursban® 4 pounds per gallon also provided complete control.[3]

Proper insect control in the nursery can increase the cost of cuttings by from 50 cents to $1 per thousand. This cost is minor when compared to total cost of establishing a plantation, and ignoring insect problems in the nursery may severely reduce survival and first-year growth of plantations.

Establishing Plantation

Planting and initial care are covered in a single section of this paper because the cottonwood plantation is not established until the crowns close, usually near the end of the first growing season. The more nearly the plantation has achieved complete use of the site by roots and leaves before weed control is stopped, the faster subsequent growth will be.

The recommended length of 20 inches for cuttings was arrived at through research on both survival and planting techniques. A cutting is most likely to root if the butt end is placed in very moist subsoil. As length is increased up to about 20 inches, the likelihood of survival is also increased. Longer cuttings are not generally recommended, since increases in survival do not justify the increase in planting cost. The cuttings should be planted 18 inches deep to take advantage of soil moisture. The deeper the cutting, the more likely that a single sprout will emerge. Multiple sprouts, enhanced by shallow planting, are undesirable. About 2 inches should be left above ground to help tractor operators see the rows during early cultivation (figs. 8, 9).

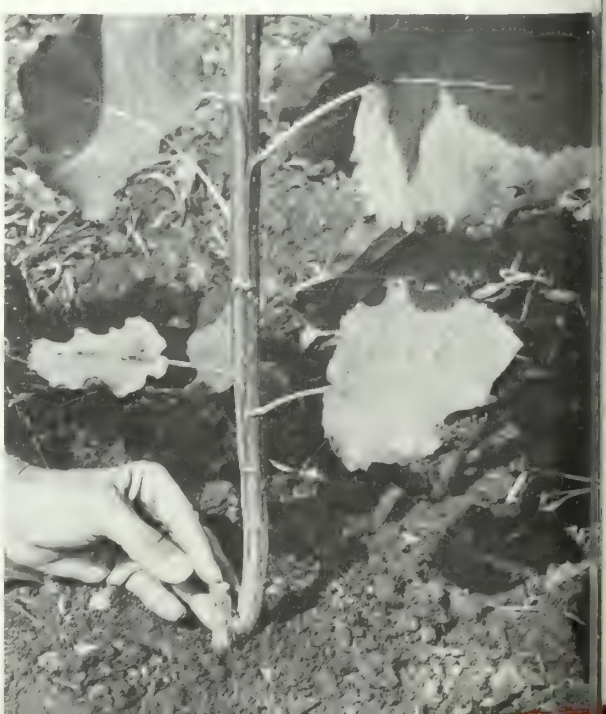
The planting season in the Southern United States extends from December through early March. Planting holes can be punched into the ground by hand with a rod 1 inch in diameter. A step at 18 inches and a handle at 3 feet can be bent into the rod (fig. 10); the end should be sharpened. Narrow subsoil trenches opened by machine can be handplanted efficiently, but there should be no foot on the subsoil chisel. With either method, the cutting should be placed butt end down and the opening around it should be closed by a kick of the heel.

An efficient planting machine has been developed. It opens a trench with a subsoil chisel (fig. 11) and includes racks for carrying cuttings and a sulky seat for a man who inserts cuttings in the trench. The machine is mounted on a three-point hitch and requires a trac-

[3] Personal communication from R. C. Morris, Principal Entomologist, Southern Forest Experiment Station, Pineville, La. Mention of trade names is solely to identify materials used in these tests and is not intended for endorsement by the U.S. Department of Agriculture.

Figure 8.—Two inches should be left exposed when t cutting is planted.

Figure 9.—When cuttings are planted properly, a sing healthy sprout normally develops.



igure 10.—A rod 1 inch in diameter with a step and a handle bent into it punches holes of the right size and depth.

igure 11.—The planting machine includes a chisel that opens a narrow trench 18 inches deep.

tor of at least 85 drawbar hp. to pull efficiently through all soils. With less power, the chisel hangs up on roots and small stumps. The subsoil bar should be made of T-1 or stronger steel and measure 36 inches by 6 inches by 1/2 inch. Depth of cut is set for 18 inches. The planting machine can be made in a welding shop for about $400.

With machine planting the cutting is simply pressed to the bottom of the fissure and left in an upright position, large end down. Some caving of the trench occurs immediately, but frequent heavy rains are relied upon to seal the cutting in the soil. Advantage is thus taken of the trench to allow maximum rainfall penetration into the soil. Cuttings soaked in water for at least 3 days before planting remain wet in the trench during the winter for periods of up to 3 weeks without rain.

Uniform spacing within and between rows is important to assure efficient machine cultivation. To achieve the desired spacing the site must be crossmarked in advance of planting (fig. 12). One means of showing the planter where to insert cuttings within rows is to properly space spring-loaded plow shanks on a toolbar attached to the three-point hitch of a farm tractor. Small plows on the ends of the shanks will leave clear marks that are not easily obliterated by rain or other causes. An ordinary marker must be mounted on the tractor to properly space subsequent rows. Thirty acres can be marked daily with this equipment.

A guide bar across the front of the tractor that pulls the planting machine helps the driver line up on previously planted rows. Hanging chains on the ends of the bar aid the driver in maintaining precise distances.

The initial spacing between cottonwoods is very important, because stagnation can occur and the trees do not recover from it quickly. The objective should be to provide sufficient room for trees to grow at the maximum rate until they reach pulpwood size and a thinning is profitable.

Studies of stands through the sixth growing season indicate that a spacing of 12 by 12 feet is about right to maintain growth to a size suitable for pulpwood thinning. At that age these studies had an average yield of 2.2 cords per acre per year. Spacings of 8 by 9 feet gave equal yields but the trees averaged over 1 inch smaller in diameter than trees spaced 12 feet apart (5.6 inches vs. 6.7 inches). Height increase of dominant trees averaged about 11 feet per year at both spacings. Spacings of 16 by 18 feet have been tried, but they appear to offer no advantages. Considerable volume was lost because trees planted that far apart took 8 years to fully occupy the site. In addition, large live limbs persisted low on the main bole.

With some species any form of cultivation that cuts roots near the surface of the ground is detrimental to

Figure 12.—Cuttings are inserted in th subsoil trench at crossmarks.

the growth of young trees. It was long believed that cottonwoods reacted in this manner. However, thorough first-year cultivation to a depth of 6 inches throughout the planting site hastens crown closure in cottonwood. Deep cultivation provides insulation against evaporation of subsurface moisture, and the loose soil permits rapid percolation during hard summer rains. The increased aeration is also probably beneficial.

Research and experience of commercial planters show that weeds need to be kept completely away from the growing trees until the crowns close. Most commercial planters are straddle-plowing one row at a time with a conventional four-row front-mounted farm cultivator until the trees are about 2 feet tall. Cultivators equipped with shovel-type plows allow tillage close to the young plant and avoid hand hoeing (fig. 13). Inside these plows are shields which regulate the flow of dirt beside the tree and keep large chunks of debris and clods from striking the tender sprouts. The first plowing is usually done in the direction of planting, and the second cultivation is done across th planting rows. Shields should be removed for the thir cultivation, but straddle-plowing should be continue until trees are so tall that the toolbar is likely to dam age the trees. When weed growth between rows be comes heavy, the plows on the rear toolbar should b removed and a 7-foot tandem disk or spring-loade chisel plows substituted. To make these changes th set of the tractor wheels must be altered.

When the trees are too tall to straddle, some opera tors remove the cultivators and pull a 7-foot tanden disk set to cut as deeply as possible (fig. 14). In th last cultivation, which should be done in the direction of planting, only the front section of the tandem disk i needed, and it should be set at a sharp angle to cove grass and weeds around the base of the trees wit dirt. Dirt piled as high as 12 to 18 inches will aid th growth of cottonwood. The ditch formed between th rows will collect water during periods of heavy precip itation and aid future tree growth. In late summe guards may be needed over the tractor tires to pre

Figure 13.—Weeds must be controlled as closely as possible to the trees (left). Front-mounted plows are recommended for early cultivation because they are easiest for the tractor operator to direct precisely (right).

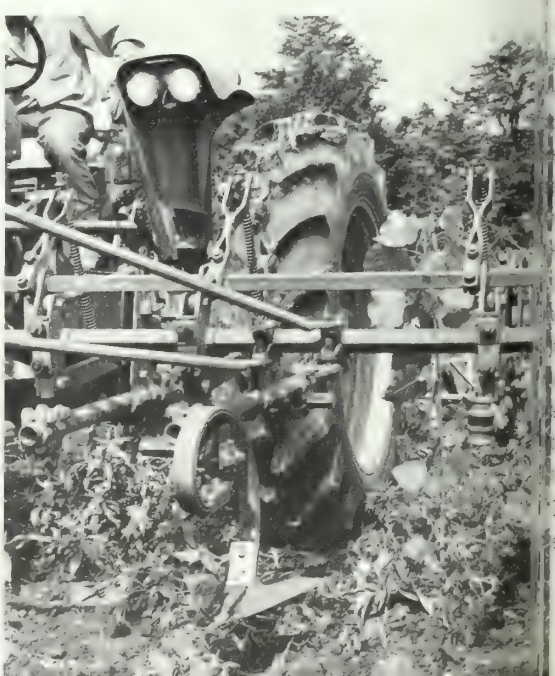


Figure 14.—When trees get too large to pass under a tractor toolbar without stem breakage, cultivation can be done speedily within rows with disk (left) or springtooth (right) harrows.

nt breaking of limbs. Fifty-five gallon drums cut in lf and mounted on the tractor frame in front of the ar wheels afford the necessary protection.

Mechanical cultivation early in the growing season eatly improves survival of trees, and intensive culti- tion throughout the first year doubles or triples the owth that can be expected where minimal weed ntrol is practiced. A prime tenet of weed control is to ow the weeds when they are small and doing little mage to trees. At that time the operator can easily e the trees, and weeds are less likely to get out of nd if there is an extended period of wet weather.

Some hand hoeing may be necessary where vines e present. A bad condition usually develops in wet ots or where morning glory **(Ipomoea** sp.), honeyckle **(Lonicera japonica** Thunb.), or wild bean **pios americana** Medic.) have become concentrat- and were not eliminated by site preparation or ear- cultivation. If they are not controlled, vines too se to the stems to be cut by machine will quickly mb into the tops of the young trees and cause conerable damage.

Other than the preemergence herbicides described connection with site preparation, no chemicals have en tested sufficiently to recommend their use for ed control in cottonwood plantations. Cottonwood s a high tolerance for some herbicides that have en screened **(9),** but no herbicide has been develed that spares broadleaved trees and kills weeds er they have emerged from their seeds. On recently ared ground preemergence chemicals are effective y for a short period in the spring of the first year. wever, early-season protection may eliminate early tivation and justify the cost of $3 to $5 per acre uired to apply a band of chemicals 2 feet on each e of a tree row. Chemicals other than preemerge herbicides cannot be recommended even on a t scale without further research.

Cultivation costs may range from $10 to $15 per e, depending on amount of handwork required. With no hoeing, about $11 per acre is the current cost to maintain a commercial plantation in a weed-free condition. Where Johnson grass is plentiful, costs may run over $15 per acre for clean cultivation.

Protection

A rapidly growing cottonwood stand contains an unusually high volume of succulent tissue that is attractive to animals and insects. The bark is soft and provides little protection against wildfire. Leaf and stem diseases have given some trouble in the South. Thus, the plantation manager must guard against fire, animals, insects, and diseases, any one of which may severely reduce growth or even destroy plantations.

The first year is the only time when protection from deer is necessary. Domestic livestock should be excluded for a somewhat longer period — until the trees are strong enough to withstand riding-down by large animals. Even then, only limited grazing should be allowed to avoid soil compaction. Deer, rabbits, and domestic livestock will occasionally strip bark from trees during the winter, but such damage is unlikely after the corky bark begins to develop early in the second year. Deer and livestock can be excluded from the plantation during the first year or two through use of the brush fence described earlier. Beavers that reside along streams and sometimes those that migrate along major rivers can quickly decimate a cottonwood plantation. Control of this animal should be assured before plantations are established. State forestry commissions and game commissions are good sources of information about regulations regarding control.

Insects can be particularly damaging in cottonwood plantations because they can reproduce rapidly to take advantage of the concentration of succulent plant tissue. By dipping the moist cuttings in phorate dust, insect problems early in the first year can be prevented. In this manner, attacks by the cottonwood twig borer are prevented until trees are well established.

This borer attacks the growing branch tips and prevents the twigs from elongating normally. Terminal tips are often killed, after which the tree either produces more than one leader or develops a crooked stem when a new leader grows around the wound. The caterpillar that does the damage is whitish with a brown head, and about 1/4-inch long when full grown. The adult is a grey moth. Treatment with phorate is the only control that has proven effective thus far. Cottonwood leaf beetles **(Chrysomela scripta** F.) eat the foliage and, when it is exhausted, the growing tips of the tree. They can reduce growth and deform stems, particularly on trees less than 1 year old. Most epidemics occur late in the growing season but the insect can hit at any time. The adult is 1/4-inch long, has black and yellow stripes, and looks much like a potato beetle. The larvae, which are black, grow to 1/2 inch in length and give off a pungent odor when disturbed. In nature, the insect is controlled by lady beetles, which feed on eggs and pupae. Insecticides can be applied as a last resort when it is clear that losses would be very large if no treatment were applied. The currently recommended treatment is 14 ounces per acre of 95 percent Cythion® ULV applied aerially or with a tractor-mounted mist blower.

The cottonwood root and stem borer **(Paranthrene dollii** Neum.), a clear-wing moth, is sometimes troublesome. The adult has a brown body and dark wings; wingspread is about 1–1/2 inches. The larvae make tunnels as long as 6 inches in the pith and wood of young root crowns and lower stems. An important indication of attack is the hole that is kept open to the outside for the escape of the adult moth. The caterpillar is white or pinkish, has a broad head, and is about 1 inch long. Treatment of cuttings with systemic insecticide protects the tree during the first year **(11).**

Insects seem to concentrate their attacks on weak trees, particularly those growing on poor sites. Hence, careful site selection and clear cultivation reduce likelihood of damage by producing healthy, vigorous trees.

No important disease has been epidemic in cottonwood plantations established in the South. The poplar canker **(Cytospora chrysosperma** Fr.) frequently kills some young trees that have low vigor or are weakened by other agents. In latitudes near Cairo, Illinois, severe damage from the poplar canker has been experienced in plantations where moisture stress caused poor growth of planted trees and where an early hard frost caused some bark damage. Cool, wet weather is ideal for development of the cankers. Spores that start the cankers must gain entry to the wood; therefore, wounding late in the growing season (as through pruning) should be avoided. Similar cankers of other species (primarily **Hypomyces solani** (Mart.) Snyd. & Hans. and **Phomopsis macroscarpa** Kobayashi & Chibi) occasionally infect cottonwood in the South **(4).**

A rust fungus of the genus **Melampsora** sometimes defoliates cottonwood of all ages. The rust forms yellow spores on the lower sides of the leaves, and dead, leather-colored patches appear on the tops of leaves. Slight evidence of this disease is noticeable almost every year, and sometimes trees are almost completely defoliated. Damage in the South is limited to loss in growth, and no chemical treatments are recommended. Genetically resistant cottonwood strains are being developed. Disease incidence is extremely variable between trees, and scientists are incorporating resistance in new, fast-growing clones.

Fire protection is essential in cottonwood plantations after the first year. The light shade afforded by cottonwood crowns encourages growth of understory plants. These plants often wither in the dry southern autumns and leaves from the trees add to the fuel. Under dry conditions, a fire can easily destroy a plantation. Fire breaks should be made along roads adjoining plantations and at intervals of no more than 1,000 feet within plantations. These breaks should be at least 15 feet wide. In addition, frequent patrols or other means must be provided for maintaining a close watch during periods of high fire danger.

Costs of protection will vary from year to year, but averages from experimental and commercial operations indicate an annual expense of about $2 per acre. In the first year, the money will be spent on insect control. In later years, it will be divided between insect control and fire protection.

Plantation Management After Establishment

Since cottonwood is intolerant of shade, a fine balance must be struck between sufficient light for rapid tree growth and sufficient side shade to aid in natural pruning. Where artificial pruning is planned, the manager can afford to give trees more growing space than where natural pruning is relied upon. He must balance maximum value increment on individual trees with that for the stand as a whole, however.

Thinning is related to initial spacing, which is further related to the goal of management. Most planters will be aiming for as quick a return from the first thinning as possible. They will continue thinning until a final harvest of large and valuable saw and veneer logs. To achieve maximum growth, basal area should not be

owed to exceed 80 to 90 square feet per acre. gular and heavy thinning at 3- to 5-year intervals ll be necessary.

An initial spacing of 12 by 12 feet is recommended most purposes. Survival will be as high as 90 per- nt at the end of the first year if all recommendations e followed and if extreme droughts do not occur dur- the growing season. In sawtimber rotations, suc- ssful plantations are those where 190 to 240 trees e of pulpwood size at the time of the first thinning . 15). For very short pulpwood rotations, a 10- by -foot spacing may be desirable, in which case out 325 trees should reach minimum pulpwood size ore thinning.

Figure 15.—Six-year-old plantation ready for first thinning, in which every other row will be removed.

A stand under average growing conditions and on a ood site should develop and be thinned about as wn in table 1, if pulpwood, sawtimber, and veneer per are to be produced.

The yields in table 1 are typical of good sites for a - and veneer-timber rotation (fig. 16). The cut at proximately age 18 would be primarily for sawtim- , although a few logs would be suitable for veneer. wever, about 60 percent of the logs cut at age 28 uld be suitable for veneer and the other 40 percent

Table 1.—**Estimated yields in a saw- and veneer-timber rotation**

Age (years)	Trees	Average d.b.h.	Periodic cuts	
	Number	Inches	Cords	Bd. ft., Doyle rule
8	200	8	8	
12	100	12	13	
18	50	18	4	5,850
28	25	28	18	23,600
			43	29,450

would be good quality saw logs. Tops would make up the pulpwood cut at age 28. At age 8 the thinning would remove alternate rows of trees in one direction, and at age 12 alternate rows in the other direction would be removed in the second thinning. The third thinning would remove the damaged and weak trees as well as those selected to release final crop trees. Some trees will be too small to harvest at the first thinning and may even die before reaching merchantable

Figure 16.—A 10-year-old plantation near Greenville, Mississippi.

size. Mortality is considered in the table by showing the number of trees reaching merchantable size as only two-thirds of those planted. This survival rate is about average for good sites.

Some landowners, particularly pulp companies, may want to minimize rotation length to produce wood rapidly, harvest, and reinvest by planting again. Short rotations provide the opportunity to inject genetically improved planting stock at frequent intervals. For a short pulpwood rotation a spacing of 10 by 10 feet and 325 survivors at age 6 are assumed. The yields at this age and in the other two cuts recommended for maximum volume production of cordwood are shown in table 2.

Table 2.—**Pulpwood rotation yields**

Age (years)	Number of trees left at indicated age		Cuts
	Trees per acre	D.b.h.	
	Number	Inches	Cords
6	200	6.4	4.8
9	120	9.0	8.4
12	0	12.0	32.5
			45.7

Of course, timing of thinning and of final harvest can be varied considerably to suit the landowner's needs. Whatever the combination, thinning should never be delayed until cottonwood growth slackens. In the early stages of growth (less than 6 inches in diameter) the number of trees must be the principal guide. As the trees reach minimum merchantable size, basal area becomes a meaningful measure of stand density. Spacing studies have shown that this basal area should not be allowed to exceed 90 on the best sites before the stand is thinned. After the last thinning the stand can be allowed to reach a basal area as high as 120 square feet before the final harvest.

On sites that are rated as mediocre for cottonwood, but where survival is good, yields can be expected to be about a third of those for the best sites. Soils rated good for cottonwood will yield about two-thirds the volumes expected from superior soils.

During all harvests, stumps should be cut flush (or nearly so) with the ground. Low stumps deteriorate rapidly and do not hinder vehicle access during future cuts. In addition, low cutting helps to avoid the expense of site clearing after the final harvest.

The expense of establishing future plantations can be kept down by mowing the understories in established plantations at about 4-year intervals. A heavy rotary mower mounted on a wheel tractor with a three-point hitch can be set to run 12 to 18 inches off the ground. This treatment leaves fine game food and yet restrains sprouts of other tree species. If the owner does not wish to grow game food, he may choose to disk at intervals of 1 or 2 years during the spring or early summer to control undesirable vegetation and enhance tree growth. Such disking is most beneficial when done as soon as tops of thinned trees have deteriorated somewhat. When disking, it is wise to straddle stumps for safety as well as to cut stumps as much as possible to hold down sprouting.

Some planters may wish to consider pruning selected crop trees at an early date. Although lower limbs of the trees begin dying in their second year, it is not until about age 4 that many of these limbs fall from the tree boles (fig. 17). After the second growing season some limbs can be knocked off the lower bole with a light club. In addition, research shows that pruning of live limbs to half the tree height does not reduce diameter or height growth of the main bole. Wounds as large as 3 inches in diameter can be expected to heal in 1 year **(5).** To avoid canker diseases, wounds should not be created during the winter. The best time to prune appears to be spring or summer. Research

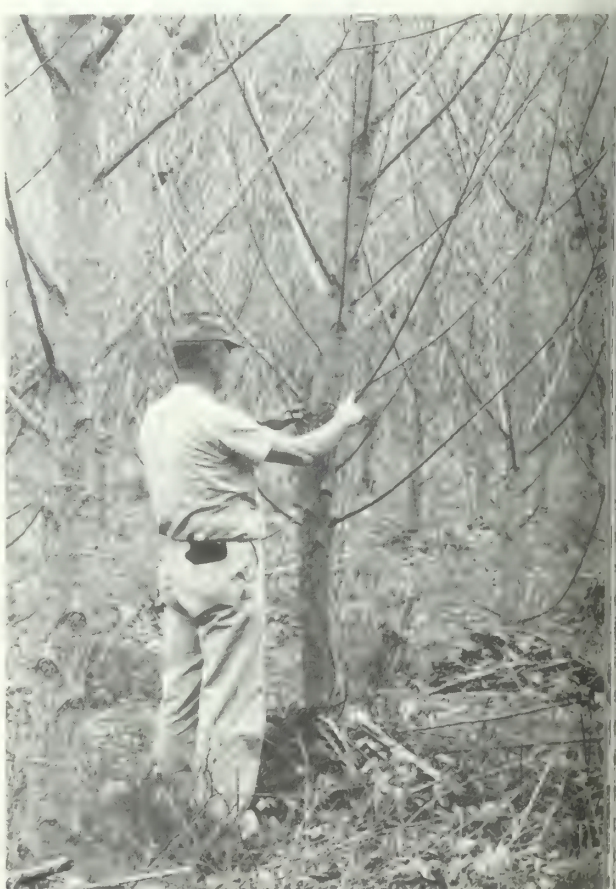


Figure 17.—In this 2-year-old plantation lower limbs are dying and some have fallen.

ıder way at the Southern Hardwoods Laboratory ould soon develop more precise information for tim- g of pruning. Now it does not appear practical or ofitable to go above a height of 32 feet with artifi- al pruning. Some believe that natural limb-fall should relied on above about 20 feet, because special uipment is needed for a man to safely prune above s height. At any rate, limbs should be pruned flush th the bole to hasten callusing and complete healing the wound.

Pruning to a height of about 9 feet can be easily complished with handsaws or small powersaws. y pruning above this height should be from a solid tform fixed to a tractor. If equipment is available platform can be raised and lowered as with a fork- . To avoid danger of falling, guardrails should be ovided for the pruner. Safety glasses or goggles are commended to avoid eye damage from twigs, chips, d sawdust.

Increases in the value class (pulpwood to sawtim- r) or the grade of the main stem will add to income the time the plantation is harvested. For example, tonwood grown to 28 inches in diameter would be rth six times as much for use as veneer and sawtim- r per unit of common measure than it would for lpwood, assuming stumpage prices of $5 per cord d $57 per thousand board feet (Doyle rule). In addi- n, pruning increases the amount of clear veneer that n be made from the butt log of a 28-inch tree by re than 30 percent.

If the stumps left after final harvest are no more n 2 inches above ground, a major land-clearing job l not be needed to establish a new plantation. me piling of tops and debris will be necessary to tect the next crop from deer. In addition, the site uld be disked with a heavy disk late in the fall be- e the winter of replanting. Planting rows should be anged to avoid recently cut stumps in the direction which the planting machine will be pulled. Every rt should be made to obtain genetically superior nting stock for the new plantation. At today's ces, establishment of a second plantation immedi- ly following the final harvest of the first should cost 0 to $60 per acre.

After the first year, cottonwood plantations provide e habitat for deer, turkey, quail, rabbits, and other me. The cover is excellent and the understory con- s a profusion of desirable food plants such as wberry and vetch. In many instances it may be pos- e for the cottonwood planter to increase the returns n his investment by selling hunting rights. Some mercial planters and hunting organizations are ng to increase the game-carrying capacity of plan- ons by seeding highly nutritious winter crops for wildlife. They hope that these crops will carry unusually high game populations through the months of December-February, when food is normally in short supply.

Investment Opportunities

Cottonwood is highly marketable for a wide range of products. It has long been a favored species for beverage cases. The wood is light in weight but tough, and its whiteness provides an excellent printing surface. Veneer buyers seek the species for core stock and bonding in furniture plywood. In some cases it is used as face veneer. As factory lumber cottonwood is used in frames of overstuffed furniture and for other furniture parts. The wood is a favorite for production of matches, toothpicks, and excelsior. In addition, it is desirable for pulps that are made into magazine paper on which photographs can be reproduced with unusual clarity.

Currently, cottonwood represents only 3 percent of the available timber volume in the Lower Valley of the Mississippi River — the principal region suitable for its growth. One reason for this low percentage is that cottonwood grows well only where moisture and soil conditions are good. Another is that natural stands of cottonwood are not being formed as often as they once were. The U.S. Corps of Engineers now controls the meanderings of the Mississippi River and its major tributaries to reduce the formation of new ground, which is essential for cottonwood seeding. Plantations are needed to supply an expanding market that is currently dependent upon a shrinking resource.

There are several other considerations that must enter into decisions to grow cottonwood. First, highly profitable agricultural lands compete for some sites capable of supporting cottonwood, though lands subject to regular overflows of rivers are better risks for tree plantations than other crops. Second, large expenditures are necessary to establish plantations. If the landowner is already in a farming enterprise, much equipment will be available. Otherwise, equipment must be purchased. One operation in which approximately 1,250 acres of land are planted annually required the following equipment:

Article	Number	Cost
93 to 100 hp. rowcrop tractors	5	$40,000
Four-row front-mount cultivators	5	5,200
Heavy-duty 7-foot tandem disks	5	8,250
Tree planter and auxiliary equipment	5	2,500

Heavy-duty high dump rake	1	1,100
Bush hog mower	1	750
Bench type swing saw	1	250
Trailer-mounted mist blower	1	1,500
Trailer-mounted acetylene and electric welder	1	1,000
Bulldozer blade for farm tractor mount	1	900
Air compressor	1	300
Heavy-duty farm trailer	1	1,000
Pump and hose	1	175
	Total	$62,975

Other costs that may be incurred during the first year of operation were discussed in previous sections. The approximate costs per acre are:

Site selection	$ 1.00
Site preparation (land clearing, raking, burning, and disking)	75.00
Planting stock	3.00
Planting	12.00
Cultivation	12.00
Insect control	2.20
Trucking	2.50
Total	$107.70

These figures are for units of at least 100 acres on forested sites. Costs would be somewhat higher on smaller units.

Annual costs and periodic costs must be incurred; below are estimated averages for the batture lands of the lower Mississippi River:

Annual Costs per Acre	
Taxes	$0.50
Management	.50
Fire protection	.50
Total	$1.50

Periodic Costs per Acre	
Mowing (every fourth year)	$4.00
Insect protection (every eighth year)	2.20
Total	$6.20

Reestablishment costs in subsequent rotations will be less than the initial establishment costs when land clearing is involved. The total for starting the second plantation is estimated at $51.70.

If circumstances permit, cottonwood can be set o previously cleared land. Here the cost of initial estab lishment would vary from $50 to $75 per acre, de pending on amount of site preparation required. Cost will be highest where deep plowing is essential t break up a sod or plowpan.

On pulpwood rotations, a rate of return of mor than 5 percent can be expected on good sites if estab lishment costs total $125 and pulpwood sells at its cu rent price of about $4 per cord. If $6 per cord can b anticipated, the same establishment investment woul earn in excess of 9 percent. If circumstances perm planting cottonwood on previously cleared land, the initial costs of about $55 per acre might be required With pulpwood prices at $4 per cord, the investmer would earn 10 percent; at $6 per cord the rate of re turn would be in excess of 15 percent.

Regardless of whether present or improved stump age prices are assumed for the future, raising cottor wood for sawtimber is more lucrative than growin pulpwood alone. On good sites where the land mus first be cleared, the rate of return will range from 7 t 12 percent, depending on choice of future prices.

For a detailed discussion of financial consideration in growing and harvesting cottonwood, the reader referred to "Investment Guide for Cottonwood Plan ers" **(2).**

Planting Adverse Sites

Planting of unrooted cottonwood cuttings and cult vation through the first growing season are recom mended only for the sites and conditions specified ea lier in the paper. Growth is so rapid and response t cultivation is so dramatic that the species must also b considered for planting on sites other than those de scribed.

One approach to adverse conditions that show considerable promise is improvement of the site befor planting. Sustained high growth rates for cottonwoo have not been obtained on heavy soils that are com pacted, poorly drained, or extremely high in clay co tent. Excellent early survival and growth have bee achieved on such soils after careful site preparatio and planting of 20-inch cuttings. Experiments therefo are under way to see whether good growth can b sustained through initial deep plowing, mounding bedding, and deep plowing between rows of develo ing trees. Results of this research must be obtaine before the procedures can be recommended.

In some cases, planting techniques can be altere with good results. For example, research has show that seedlings are better able to withstand shallo flooding during the growing season than unrooted cu tings **(8).** On sites subject to shallow flooding, see

gs should be planted firmly with the rootcollar at ound level and about 25 inches of stem above ound. In the South, planting should be done in late vember or early December before the planting site flooded by winter rains. Cultivation should proceed er the site dries in late spring or early summer. owth on these areas will be considerably slower n on well-drained sites, but land values are lower.

On sites that are subject to deep overflows that y last for a number of weeks, some success has en obtained with long, rooted cuttings planted eply. A procedure has been developed sufficiently field use on a pilot scale. One- or two-year-old rsery stock is lifted with a deep cutting blade to tain 24 inches of cutting from below ground with ne roots attached and a sprout whip 16 to 20 feet g.

The top is pruned to leave a single stem, and the low-ground portion is pruned so that most roots do extend out more than 4 to 6 inches. An 8-inch sthole auger mounted on the back of a tractor is d to bore holes 40 inches deep. Boring should be ne when the sites are dry and equipment can be erated easily. The rooted cuttings are lifted and nted after they are dormant. Growth the first year oor, but these long whips do well thereafter. Cultiion speeds growth but is not essential.

Where the ground freezes deeply in the winter, bet survival has been obtained with deeply planted edlings than with cuttings. Research near Wickliffe, ntucky, showed that seedlings survive better and more resistant to canker diseases on the stem. The her resistance of seedlings is due at least partly to ir developing a corkier bark than sprouts from cutigs in northern climates.

Literature Cited

Bearce, G. D.
1918. The commercial culture of cottonwood. Ohio Forest. 10(1): 3-8.

2. Dutrow, G. F., McKnight, J. S., and Guttenberg, S. 1970. Investment guide for cottonwood planters. USDA Forest Serv. Res. Pap. SO-59, 15p S. Forest Exp. Sta., New Orleans, La.
3. Farmer, R. E., Jr., and McKnight, J. S. 1967. **Populus:** A bibliography of world literature, 1854-1963. USDA Forest Serv. Res. Pap. SO-27, 132 p. S. Forest Exp. Sta., New Orleans, La.
4. Filer, T. H., Jr. 1967. Pathogenicity of **Cytospora, Phomopsis,** and **Hypomyces** on **Populus deltoides.** Phytopathology 57: 978-980.
5. Johnson, R. L. 1961. Pruning cottonwood and willow oak. USDA Forest Serv. S. Forest Exp. Sta. S. Forest. Notes 136.
6. McKnight, J. S., and Biesterfeldt, R. C. 1968. Commercial cottonwood planting in the Southern United States. J. Forest. 66: 670-675.
7. Maisenhelder, L. C. 1960. Cottonwood plantations for southern bottom lands. USDA Forest Serv. S. Forest Exp. Sta. Occas. Pap. 179, 24 p.
8. Maisenhelder, L. C., and McKnight, J. S. 1968. Cottonwood seedlings best for sites subject to flooding. USDA Forest Serv. Tree Planters' Notes 19(3): 15-16.
9. Martin, J. W., and Carter, M. C. 1966. Tolerance of cottonwood to certain herbicides. Ala. Agr. Exp. Sta. Bull. 372, 17 p.
10. Mohn, C. A., Randall, W. K., and McKnight, J. S. 1970. Fourteen cottonwood clones selected for midsouth timber production. USDA Forest Serv. Res. Pap. SO-62 (in press). S. Forest Exp. Sta., New Orleans, La.
11. Morris, R. C. 1965. Controlling insect damage to southern hardwood forests. **In** Insects in southern forests, p. 114-124. La. State Univ. 14th Annu. Forest. Symp. Proc. 1964. La. State Univ. Press.

McKnight, J. S.

1970. Planting cottonwood cuttings for timber production in the South. S. Forest Exp. Sta., New Orleans, La. 17 p. (USDA Forest Serv. Res. Pap. SO-60)

High yields of eastern cottonwood can be obtained through a combination of careful site selection, thorough site preparation, cultivation during the first year, and protection from insects and grazing animals. Early and frequent thinnings are needed, and pruning should be considered, where saw and veneer logs are grown. The paper presents instructions and cost estimates for recommended treatments.

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